



Converging Information and Communication Systems

The Case of Television and Computers

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Ph.D. Thesis
CTI Ph.D. Series. No. 6

Converging Information and Communication Systems

- The Case of Television and Computers

Doctoral thesis
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Kgs. Lyngby

April 2003

¹ During the project, this programme has been closed, and the project is now under the Electronics and Communications Ph.D. programme.

Preface

When I started this Ph.D. project in early 1998, the convergence of electronic information and communication was regarded as a fairly narrow and easily defined research area. During the project, the area has grown tremendously – partly because the ongoing development has made convergence increasingly topical, partly as my studies into the matter broadened my insight and suggested a multitude of perspectives and focus areas.

Because of the ongoing development, the situation has changed from back when I started. New phenomena have emerged, and ideas, which back in 1998 seemed like science fiction, have become reality. This has made the project a demanding task to undertake. It has been necessary to be constantly aware of new developments in order to keep the research on par with – and hopefully to some extent ahead of - the real world.

While at moments quite demanding, it has been a tremendous experience to actually be in the middle of the process subject to investigation. This circumstance has – in combination with the technical emphasis of this work – made it a pleasurable necessity to achieve insight and hands-on experience in the contemporary workings of the converging sectors of television and computer/networking.

I would like to express my thanks to my supervisor, Professor Knud Erik Skouby, Director of CTI for guiding me securely through the lengthy process of the accomplishment of this project, and for providing a rich and inspiring academic and physical framework for my research. The latter is very much due to the employees at CTI and Siemens, Milano – where I had an external research stay - who deserve my gratitude for having been such stimulating and helpful colleagues.

April 2003

Alexander Gorm Oest

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1. Introduction

During the 1990's, a new information and communication phenomenon has emerged. Offering services supplementing the existing, but also new and radically different ones, the Internet has become widely used. Developing from a somewhat obscure system used by the military and universities, it has gained adoption in many private households.

Till the rise of the Internet, the best-known systems of electronic communication were television and telephony. They had gained wide adoption, television as a rich one-to-many information system, telephony as primarily a one-to-one, voice-based, communication system. These communication forms worked with specialized appliances over specialized networks.

Enter the Internet. As computers became able to communicate in networks and display richer content, they were able to assume the role of multi-purpose information and communication apparatuses. As computers and Internet developed during the 1990's they could provide any generic information and communication form known from the television and telephony areas².

Infocom defines the whole area encompassing information as well as communication³.

Definition 1: Infocom (a stipulative definition).

Apart from the already known TV- and telephone types of information and communication, the Internet gives its users the possibilities of new and different types. Phenomena such as chat, usenet and homepages differ in many respects from what's offered from the older areas of TV and telephony.

By the turn of the millennium, the television sets and telephones are still widely used. Though it is technically possible, computers and the Internet haven't taken over the services of these two old areas. Some would say: "haven't yet". And the future of this

² The term "Areas" is used to describe the separate fields of what is commonly known as Television, Telephony and Computer/Networking. Use of another term (such as sector or market) would anticipate the later choice of term for these three areas.

³ Due to the important differences in the way communication and information (both defined in the "Hardware-software Systems and Communication Networks" section) are distributed and consumed, the two terms are kept separate when relevant. When speaking of "information consumption and communication" together, the short and convenient term "infocom" is often used in this dissertation. Another widely used term is ICT, which stands for Information and Communication Technology. Due to the inclusion of the word "technology", this term does not seem to cover the *process* of communication and information consumption which is why "infocom" in many cases are preferred.

landscape of information and communication is certainly subject to many different prophecies.

Convergence is most commonly expressed as:

The ability of different network platforms to carry essentially similar kinds of services or,

The coming together of consumer devices such as the telephone, television and the computer.

Definition 2: Convergence⁴ (a lexical definition).

It has become fashionable to speak of a *convergence⁵ process* taking place between the media. This convergence is often seen as a melting together of the three areas: Computer networks, television and telephony. Many visions of this future unified communication form have been put forward. Visions of not only the appliances on which infocom take place, but also the future infrastructure, legislation, content generation and many other areas are subject to convergence considerations. It should be noted, though, that this project uses the term “convergence” also in cases where less radical effects are taking place.

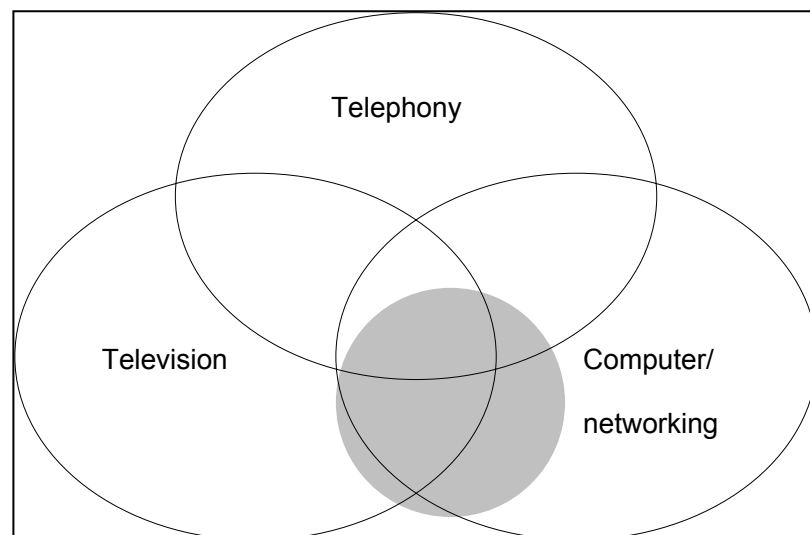


Figure 1: The convergence areas. Shaded area marks the focus of this project.

⁴ The European Commission, 1997, p.1.

⁵ In its purest form, convergence would mean that there would be one infrastructure, one appliance etc. covering *all* forms of infocom. Here, the term is used more widely, covering the current process in infocom, where various systems are coming together and influencing one another.

One of the important documents concerned with convergence is the European Commission's Green Paper of Convergence⁶ of late 1997. In accordance with Figure 1, it sees convergence as taking place between three areas (or – as it calls them – *sectors*⁷).

1.1. Promises of Convergence

Among the many promises of the expected process of convergence, three are especially interesting from the perspective of this project. These are *interoperability*, *interactivity* and *quality*. People in other fields of research might interpret the promises of convergence otherwise, in the forms of e.g. business processes, public service, or even increased understanding between peoples. Some might even see convergence as a threat. But from a perspective of the consumer, the major promise is better information and communication. The three promises presented below describe in which ways “better” can be brought about by convergence.

1.1.1. Interoperability

When two or more systems can work together to deliver a service or some content, we say that they are *interoperable*.

(ISO/TC204) “Interoperability is the ability of systems to provide services to and accept services from other systems and to use the services so exchanged to enable them to operate effectively together.”

Definition 3: Interoperability (a lexical definition).

In practical terms, interoperability coming from convergence can make it possible to use forms of communication and information on different appliances. Television sets can be used for browsing the Internet, computers can be used for voice conversation traditionally provided by phones and telephone networks. Though possibilities such as these are fascinating by themselves, the most important opportunities possibly lie in the new innovation possibilities that arise when content and services are consumed on the computer platform. Here, the flexibility, versatility and distributed intelligence of the computer opens for improved ways of accessing, viewing and storing content, issues further investigated in The TVPC Case Study.

⁶ The European Commission, 1997.

⁷ Here, probably due to the regulation perspective of the Green Paper, there is a slight difference between the definitions of the areas involved. Where the areas in this project are defined as Telephony, Television and Computer/networking, the Green Paper uses the corresponding terms of Telecommunications, Media and Information Technology. This dissertation could have adopted the terms of the Green Paper, but due to the focus on appliances rather than overall regulation, a narrower set of terms has been chosen.

The computer is a strong candidate for a future infocom appliance, but it is not at all certain, that all information will be consumed and communication carried out on computers. On the other hand, the strengths of the computer are so impressive, that the appliances of the two other converging areas must be expected to adopt at least some of the characteristics of the computers of today.

Though the terms are related, interoperability should not to be confused with compatibility, which is a narrower term mostly used within the computer area.

The ability of two or more systems or components to perform their required functions while sharing the same hardware or software environment.

Definition 4: Compatibility⁸ (a lexical definition).

1.1.2. Quality

Quality can be defined as:

“an inherent feature”

...and as:

“degree of excellence”

Definition 5: Quality⁹ (a lexical definition)

Another major area where this project focuses on the promises of convergence has to do with the quality of the delivered content. Hereby is meant the measurable type of quality in sound and picture, not for example the correctness of a documentary of the suspense value of a thriller. Improvements in quality can be categorized in two kinds: those that are incrementally better than earlier versions, and those that are radically different. Examples of the former are increased resolution and refresh rate in pictures and improved signal to noise ratio in audio equipment.

Both of the above definitions fit the two meanings, that the term “quality” assumes here. In the case of a radical improvement resulting in a fundamentally different sensory experience (as e.g. stereo sound compared to mono), the “inherent feature” is the fitting interpretation of quality. Correspondingly, the “degree of excellence” term covers the case of an incremental improvement (as e.g. the number of pixels in a display), where the improvement makes the experience “better”, but not fundamentally different.

⁸ IBID, p.39.

⁹ <http://www.webster.com/cgi-bin/dictionary> (link active per 030130)

Examples of the latter type of improvements radically altering the way users perceive the communication or information consumption process are characterised by their ability to increase the realism or sense of presence (often referred to as *immersion*). This implies a more life-like presentation, often in the form of stereoscopic images (also called 3D images) as well as surround sound. It might, however, also involve the influence of other senses than sight and hearing. Especially the senses of smell and feeling are subject to recent innovations. In this project, the term *modality* is used when referring to these subjects.

Modality: *One of the main avenues of sensation (as vision)*

Definition 6: Modality¹⁰ (a lexical definition).

The concept of virtual reality is not new, and it has been subject fantastic speculations to an extent where it seems to belong in science fiction rather than being a sensible and realistic goal. Still, this should not overshadow the fact that many forms of infocom could benefit from increased modality. Especially in the computer/networking area, improvements in modality are taking place, and the possible influence of these innovations upon the other converging areas is an important prospect of the convergence process.

1.1.3. Interactivity

The third important prospect of convergence is interactivity. This has to do with the consumer's ability to influence the form of the content. As such, it is a term that primarily is applied to information consumption rather than to communication, the latter being an inherently interactive process.

Interactive: *of, relating to, or being a two-way electronic communication system (as a telephone, cable television, or a computer) that involves a user's orders (as for information or merchandise) or responses (as to a poll).*

Definition 7: Interactivity¹¹ (a lexical definition).

While the computer for many years has been an interactive device, heavily depending on input from its user, the television appliances and content traditionally have little interactivity. The level of user's influence upon the content has been limited to selecting programmes and adjusting sound, colour and brightness. In recent years, attempts of interactive content has been introduced, but due to the lack of a return path in TV networks, most of the actual examples are of the so called "carousel interactivity" kind, where the user chooses between teletext pages or different camera

¹⁰ Merriam-Webster OnLine

¹¹ IBID

angles – i.e. a choice between different pre-defined presentations, but with no actual user influence on the content.

One future scenario could be the migration of all traditional television content onto computer networks – which would bring about interactivity through the computer networks two-way type of architecture. Another alternative, however, is a combination of infocom forms into *hybrid* infocom (as demonstrated in “The Hybrid Communication and Information Proof-of-Concept Prototype”), where some content is delivered from the TV area over traditional television networks, supplemented with information from the telephony and especially the computer/networking area. This hybrid infocom could already take place on the computers of today, but alternatively, Internet capable television sets could also prove a viable path.

1.2. Future development

Among the many possible future scenarios, the often prophesised fusion of all infocom phenomena into one isn't the only possible outcome. It can easily be imagined that future appliances, infrastructures etc. will be special-purpose devices, which can be used only for a single (or few) communication or information purposes. One can imagine that – even though convergence to some extent is bound to take place – a process of *divergence* could actually characterize the future development.

It is also difficult to be precise about the services arising from convergence. Many new services will result from technological progress within given sectors, and may not result from cross-sectoral activity at all. Others will be a direct result of cross-fertilisation between sectors, telecommunications and broadcasting for example.

Quote box 1: About the uncertainty of the future landscape of infocom¹².

A vast number of factors can influence the future development of computer/networking and television as well as telephony (which is not a focus area in this work). Obviously, there are a number of technical properties adhering to the different areas, but other factors – which might be less obvious to users – also influence this process.

In this turbulent process of change, many actors attempt to influence the development. Companies, governments, user groups etc. – many with separate and conflicting agendas – are involved in setting the standards and formats of tomorrow's infocom landscape. The prophets of future infocom must not be blind to those forces existing

¹² The European Commission, 1997, p.2.

outside of their own scientific domain. On the other hand, trying to encompass all imaginable influential factors would be futile.

1.3. Approach

Due to the fact that the Internet, convergence and divergence are phenomena taking place at present, there is no well-established set of heuristics to guide scientific analysis. A longer lasting study is difficult to conduct, as the subject of investigation is changing constantly. Of course, historical perspectives can be applied in useful ways to the infocom phenomena of the past, but in order to predict the future development, it is necessary to go beyond the notions of TV, phone and computers and apply a different perspective on the process.

It is necessary to identify the basic characteristics of communication and information consumption. From this point of departure, it is possible to identify possible development paths, obstacles to - and factors stimulating - certain developments.

This dissertation presents a set of coherent fundamental terms for describing the process of convergence. It furthermore investigates a certain segment of the convergence areas (computer/networking and television) and zooms in on a particular level – the *appliances* used for communication and information consumption. Here, answers are sought to the questions of *why* computers and the Internet over such a short time span have become so capable of supporting the infocom of other areas, and how this capability will influence the future development. Special attention is given to the issue of *flexibility* – i.e. the ability of hardware and software to adopt not only incremental improvements but also radical new forms of infocom.

The perspective of this project is mainly on the role of *standards* as determinants of development. This implies that a wide variety of standardisation aspects within the various converging areas are investigated with the aim of explaining important flexibility properties of these areas.

1.4. Purpose

These paragraphs describe the purpose of this project in broad terms. A more focused description of the field of investigation is given in the “Research problem” chapter.

In general, the aim of this Ph.D.-project is to investigate the process often referred to as convergence. However, as mentioned before, processes of divergence as well as processes unrelated to con- or divergence must be expected in the future. Therefore, it is necessary to consider possible paths of development. The purpose is not so much to actually *predict* the future development of infocom as to provide the *basis* for a more *qualified* prediction.

1.4.1. Development paths

The purpose of this Ph.D.-project is to identify possible paths of development of the future landscape of electronic communication and information consumption. This is done by suggesting different ways of development pointing out a number of factors influencing the development. These factors might be hampering development in some directions while stimulating other ways of development.

By clarifying these influential factors, it is possible to better foresee prospective infocom structures and phenomena. By identifying these paths, the Ph.D.-project suggests a basis or framework for analysis and predictions.

1.4.2. Descriptive modelling

To gain insight into these possible influential factors and paths of development, a new perspective on the process of infocom development is defined. Instead of only looking at the traditional areas of television, computers and telephony, a perspective of basic communication characteristics is suggested. The purpose is to offer an overview of the plain essentials of infocom – a re-definition of the perspective on convergence (or whatever development the future will show) *from* the household notions of computers, TVs and phones *to* a model encompassing the properties that make out electronic communication and information consumption.

With such a descriptive model, the usability of appliances, infrastructure etc. of the infocom areas of today can be identified. What's offered here is a perspective based on fundamental characteristics of communication, without the habitual thinking in traditional terms. This re-definition of perspective is necessary, because it makes little sense speaking of for example television or computers, when what is important is the *nature* of information or communication – for example whether it takes place in real-time, whether it is based on text, pictures or voice. It can also limit the perspectives of investigation when for example speaking of a “terrestrial TV network”, which basically is a one-to-many network. With a useful model of communication, it is easier to envisage possible forms of future infocom: *which* forms of *communication* and *information consumption* that take place on *which* form of *infrastructure*.

Not only will the forms of information and communication be subject to modelling. The project also suggests a perspective of layers or levels similar to that of the OSI model of the whole landscape of infocom, ranging from infrastructure over applications and appliances to legislative considerations. In this perspective, the focus of the project can be defined. Obviously, not all layers are subject to investigation. The model instead serves as an aid for defining the focus elements of the report - as well as linking to other areas of contemporary and future research.

1.4.3. Defining

In a work such as this, it is important to operate with clearly defined concepts in order to avoid confusion. In some cases, an established definition of a particular concept is available, while other concepts are in need of a proper definition that can be agreed upon among those researching the topic.

“Unless we define all these buzzwords that we use, we might as well all speak smurf language”

Unknown

Quote box 2: About the importance of a common language.

To a large extent, the modelling work aims at clarifying the process of development in present and future infocom. Thus, this work also involves evaluating existing definitions, and stipulating definitions when so suitable ones exist. This might sound trivial, but defining the concepts is not only necessary in order to provide a sound framework for the analysis, it is crucial for facilitating an understanding of this work, as a means of ensuring a shared understanding of the concepts used.

The need for clear definitions based on the nature of information and communication is pointed out in the European Commission’s Green Paper of Convergence¹³, where concerns are put forward on the issue of failing to properly define the important aspects of services. The green paper is not quite specific on the subject of which definitions are needed. However, it is clear that the definition problematic of the green paper has to do with the nature of the activity rather than the underlying technology.

¹³ The European Commission, 1997, p.21.

One option would be to continue to work with existing definitions, recognising that these remain valid for the majority of services offered and to extend, where appropriate, the principles underpinning current regulation, whilst adapting the way in which it is applied to take account of the specific characteristics of the “new” services.

A second option might be the creation of a separate category of “new” services to co-exist with existing definitions.

A third option would be the adaptation of current definitions used in telecommunications, and/or broadcasting to reflect current trends and developments.

Quote box 3: Possible options for new definitions of the converging areas, their technology, services, information and communication¹⁴.

From looking at Quote box 3, it seems the green paper fails taking a fourth option into account – i.e. the approach used in this Ph.D.-project, namely to abandon the earlier definitions and instead look at the basic characteristics of communication and information consumption (as is done in the taxonomy in a later chapter of this report).

Clearly, the definition considerations of the Green Paper are not concerned with how to define the areas (or sectors) involved in the convergence process, but with the information consumption or communication itself. Though the Green Paper is heavily concerned with regulation of infocom, whilst this Ph.D.-project focuses on more technical aspects, the modelling and definition disciplines carried out here can be useful for regulatory purposes, as they assist regulators in identifying *what* to regulate.

Due to the newness of the current development in infocom, there is no consensus as to a lexical¹⁵ definition of the word *convergence* – or for that matter to quite a number of the terms used to describe the development.

Therefore, a number of stipulative¹⁶ definitions are used in this work. Partly as tools for the analysis, partly as suggestions for future lexical definitions which can be agreed upon among people involved in the topic of this project. These definitions are primarily concerned with the less tangible concepts subject to analysis.

¹⁴ IBID, p.21.

¹⁵ A lexical definition relates the way a term is ordinarily used.

¹⁶ A stipulative definition assigns a meaning to a new or an already existing term.

In cases where lexical definitions exist (and suffice), they are used. All definitions are presented in the relevant context in the various chapters of this report¹⁷.

1.4.4. Identification

In order to properly predict the future, important factors influencing the shape of future infocom must be identified. Here, the report focuses on the inherent technical properties of the two areas subject to investigation – identifying properties relevant to the research problem and analysing them within the defined framework. The project contains an examination of a number of various formats and standards as well as interoperability and compatibility issues in infocom.

Also the economical and organisational aspects of infocom are subject to attention. The influence of standardisation traditions and processes in the various areas on the shaping of future infocom is subject to analysis. These aspects are organisational in the sense, that they have to do with the way, the work of standard setting bodies are organised. It is also economical in the sense, that market-driven standardisation, undertaken by companies, largely are driven by incentives of maximizing profits in short or long terms – whereas e.g. regional or governmental standardisation often is done with the aim of maximizing the benefit of citizens – issues further explored in the paper “New Standardisation Fora and Their Relationships with Traditional Standardisation Organisations” in the appendix.

A very important part of the project is the case studies. Here, a number of convergence phenomena are described and investigated. This helps identifying possible paths of development as well as the drivers of and obstacles to this development. For the purpose of exploring the potential of computer technology in connection with known and new forms of infocom, the three case studies partly assume an almost experimental form via their related proof-of-concept prototypes.

1.4.5. Solutions

For each case study, practical experiments have been carried out. The reason is partly to get hands-on experience in the various fields, partly to prove that the more novel concepts suggested actually do work. This work is referred to as proof-of-concept prototyping, even though – especially in the case of the TVPC – the viability already has been more or less proven by other people.

When working with the current and future landscape of infocom – mapping structures and identifying problems and opportunities – a number of relevant solutions and recommendations will become more or less obvious. This Ph.D.-project, does not have

¹⁷ A table of definitions can be found in the early pages of this work.

a “problem solving” approach as such. When relevant solutions and practices however do become obvious or when the nature of a particular problem makes it relevant, the project will contain recommendations and solutions in order to best overcome obstacles and best exploit the benefits of the systems involved in the convergence process.

1.4.6. Contribution to existing research

The main contribution of this Ph.D.-project to the existing body of knowledge is the combination of technical insight with the knowledge of market behaviour in scenarios characterised by compatibility standards. By going into fundamental technical and standardisation aspects, this study investigates the areas often regarded as a “black box” by other studies, and thus fills an important gap in the research on development of electronic information and communication.

As has been described in this section, the contribution is focused upon the following key topics:

- Identifying key techno-economic aspects and explaining their influence on the present and future development.
- Identifying possible future development paths of the convergence process.
- Modelling infocom phenomena and identifying key parameters.
- Offering a conceptual framework and stipulative definitions of concepts and phenomena.
- Proving the viability of key concepts and identifying solutions to existing problems.

The relations to existing research are further described in the “Academic Background” chapter.

1.5. Focus and Demarcations

There is a wide selection of perspectives, which can be applied on convergence. Ranging from pure technical issues such as copper and optical wires to legislative issues regulating the communication and information. Due to the complexity of the convergence scenario, a number of limitations will have to be done. This project is thus concerned with a small corner of the whole convergence area. Still, when digging into this chosen focus area, the number of relevant issues identified quickly becomes overwhelming, as areas related to those in focus also begin to appear important. Therefore, this section draws the borders of investigation.

1.5.1. Appliances

The perspective of this project is on the consumer devices¹⁸. That is among other things the TV sets, set top boxes, phones, computers, and loudspeakers that are in use in households. This area is a small section of the whole convergence area, which reaches from physical infrastructure over protocols, signal types and appliances to usage scenarios, regulation and legal aspects such as censorship and intellectual property rights – just to mention a few.

Appliances are the pieces of equipment used by the consumer to communicate or consume information – e.g. a TV set, a telephone or a computer.

Definition 8: Appliances (a stipulative definition).

The appliances are often connected to a wall outlet where the signal carrying information or communication is delivered. Therefore, this related area of infrastructure¹⁹ also plays a considerable role in this project. The same is true for the content²⁰ that is consumed on the appliances.

1.5.2. Standards and inherent characteristics

Within the defined focus area, further narrowing down is needed. When looking at appliances for home use, there is still a multitude of possible angles of attack. The specific one in this project is looking at the inherent characteristics of the various areas' appliances. These characteristics can be very basic in nature. The Internet, for example, is inherently digital, where telephony and television are only recently becoming so. But also less basic characteristics will often be seen manifested in standards and standardisation traditions in the various areas.

¹⁸ Also referred to as “appliances”.

¹⁹ Infrastructure is defined on page 5.

²⁰ Content is defined on page 5.

The inherently global nature of the Information Society calls for any standardisation

in support of its development to be similarly global. Users may want access from any

terminal to any service, independently of the technology used, or the geographical point of such access, within a multi-vendor environment. A major objective for standardisation therefore is to achieve interoperability between networks and services.

Even though the Information Society is global, standardisation can start at regional level, provided that players from other regions can participate in the activities. The workshop mechanism has the potential to offer the platform for consensus-building while it also allows European players to increase their impact on the international standardisation scene.

Quote box 4: The importance of standardisation²¹.

Certainly, *standardisation* is one of the prime areas of focus of this project. Here, a number of theories explaining development, market behaviour and other interesting issues exist. They form the bulk of the theory apparatus for this project.

But the appliances do not work by themselves. They are merely tools for communicating or consuming information. Therefore, not only the devices, but also the content of information and communication, as well as the infrastructure on which it runs - is subject to investigation. As is shown, the content can assume different forms – for example real-time communication in wires or videocassette-tapes. The interplay between these forms of hard- and software both within and across areas is an important area, where explanations of the development and pointers to future development are sought.

²¹ The European Commission, 1997, p.27.

1.5.3. Tech push

Approaches to technical development are often categorized as either technology push or demand (or market-) pull. A tech-push approach focuses on the technical development and the thereof derived new possibilities as the prime driver of technical change. The demand-pull approach puts the emphasis on the market's demand as determining the direction of innovation activities. This Ph.D. project does not go into detail with a discussion of whether tech push or demand-pull is the prime determinant of the convergence process.

The focus, however, is on technical properties, and thus, the approach necessarily becomes a tech push one. This does not imply that demand-pull factors are insignificant, they just aren't the main focus of this work.

1.5.4. Flexibility

There are many aspects of infocom, which can be regarded as crucial to the development. Among those, one specific property has the special attention in this project. This property is *flexibility*. This aspect is important, because it enables the appliances of the areas to adopt the new and improved forms of communication, which appear during the process of convergence.

Flexibility can exist virtually everywhere in the landscape of convergence. One can speak of the flexibility of infrastructure, the flexibility of organisations, of legislation etc. But having its focus on the appliances of the converging areas, this is where this project's search for explanations takes place.

Flexibility is not only within the area of appliances. Also the standards and standardisation procedures in the various areas can be characterised by more or less flexibility, which is why the area of standardisation also is investigated with the purpose of clarifying the status of flexibility.

1.5.5. Technology, economy and the surrounding environment

The focus on technical issues does not exclude other considerations from this PhD-project. Firstly, as indicated by the bulk of the theoretical material used, there is much focus on economical issues – especially the behaviour of markets in standards adoption processes. Besides its technical side, standardization is very much an economic and social undertaking, where e.g. concerns of national and regional economy as well as public utility come into play.

Thus, the focus to a large extent expands to the economic incentives that influence the convergence process – incentives of users as well as suppliers and in some cases even governments. Furthermore, topics such as usage scenarios and the importance of

social, private support networks as determinants of development are subject to attention. Still, the most explicit attention is dedicated the technical and standardization-economical issues, whereas the social issues play more implicit roles.

1.5.6. Cases

The empirical part of the project consists of a number of case studies, each having a related proof-of-concept prototype. There are three larger studies where the flexibility and capability of the computer and its networking facilities are explored and compared to that of the television area.

The case topics are chosen with the purpose of illustrating key areas in the convergence process. The three main cases are concerned with the relationship between the television and computer/networking area. One, “Hybrid Communication and Information” explores the possibilities of combining communication and information consumption from the world of television with the computer and the Internet. Another, the TVPC explores the usability of computers in the role of traditional combos of television sets, VCRs and set top boxes. Finally, the Modality case explores the possibilities of increasing modality on the computer compared to television.

1.5.7. Time and History

In this Ph.D. project, multiple case studies are used to analyse the convergence process. In its classical form, a case study investigates a *contemporary* phenomenon²². Accordingly, the main part of case investigation is about the recent and present development.

However, to fully understand the nature of a particular area – be it television, telephony or computer/networking - it can be worthwhile looking at the history, which has led to the system as it is today. Here, explanations of the inherent properties of the areas can be found. Furthermore, a historical perspective can be useful to understanding systems and technologies in their current context²³ and to giving estimates of possible future shapes of infocom.

The future perspective of this work is fairly short – typically five to ten years. Many exotic forms of infocom can be expected in the long run. In a few places (particularly

²² Yin, 1994, p. 13.

²³ This is done by the “The Shaping of Television” report in the appendix, where the origin of today’s TV is investigated.

the outlook section), this dissertation discusses the very long-term perspectives, but science-fiction scenarios of e.g. 30 years from now are not the main consideration.

1.5.8. Computer/networking and Television

Among the tree areas, which are defined as the important ones in the convergence process, the main point of departure is on the computer/networking area, and focus is on the convergence between this area and *television*, not *telephony*. This is because the Internet makes an interesting area of analysis, as it shows a far quicker rate of development than television and telephony. As the focus is on the convergence between computer/networking and television, much effort will also be devoted to analysing the relevant standard and standardisation processes in the television area. This focus area has been of interest to the European Commission, who regards it as an area of much potential development.

Despite current limitations a number of applications are closing the gap between smart television and video Internet. The area where these two areas converge currently constitutes the most fertile ground for innovation and entrepreneurial activity – as well as for creation of entirely new types of content. Innovative forms of graphic-rich “Internet channels” are building on the creativity of previously separate métiers of video production, computer imaging and information management. Similarly, high-end networked video-games are building devoted constituencies of players across national borders. In a seamless and scaleable digital environment, innovative hybrid multimedia applications are appearing...

Quote box 5: Reasons for the importance of the convergence area between computer/networking and television ²⁴.

1.5.9. Private use

Another aspect of the perspective applied here is, that the focus is on private households rather than e.g. on business-to-business, academic or military applications. Thus, the main focus is the consumption of information. One professional area subject to investigation, however, is content provision and generation. This is due to the fact that the availability of content is a necessary precondition for a successful introduction of any improvement or innovation. If suitable content is not available – or for that matter a suitable appliance – a chicken-and-egg problem is likely to be reality, hampering the incentive of supplying content when there are no or few potential users and vice versa.

²⁴ The European Commission, 1997, p.11.

Another important aspect of content provision can be observed in situations, where private individuals or organisations naturally assume roles of content providers, as is the case in for example a traditional phone conversation. Thus, the focus to a large extent is on private use such as entertainment and interpersonal communication, as these are the forms of use most common among private users.

1.5.10. Fixed network infocom

An important topic in today's convergence debate is *mobility*, which is first and foremost represented by cellular or mobile phones. Mobility certainly has important consequences to the future patterns of infocom. Though relevant, issues of mobility are left out of this project in favour of the communication and information consumption taking place “at home”.



Figure 2: This project is not concerned with mobile infocom.

This does not altogether exclude wireless communication from having a place in this report. Phenomena such as FWA (fixed wireless access) WLAN (wireless local area network) and remote controls are examples of the fact that the infocom of households does not necessarily have to run through copper or optical fibres. Still, with the main focus of this project on appliances rather than infrastructure, the issues that one will miss here are rather related to the mobile communication devices than the communication networks.

1.5.11. Geographic focus

The main focus is the European scenario, but to a large extent, the situation in U.S.A. is also analysed. This is particularly due to the fact that much of the content consumed in the television area is American. Talk shows and Hollywood movie productions are important content in Europe as well. Therefore, the U.S. development in content formats and standards has significant influence upon the scenario in Europe.

1.6. The structure of the project

Before trying to answer the research questions posed in this project, it is necessary to define the *conceptual framework* in which we operate. This framework is defined on the basis of a number of fundamental *conceptual questions* regarding how to view and define the topic of the project. For this purpose, a *conceptual study* is carried out, which provide the answers to the questions asked, resulting in a taxonomy of information and communication.

The overall *research problem* of the project are formulated as few questions specifying the problems which are investigated. They are, in turn, broken down into derived *research questions*, which guide the further analysis. This is due to the broadness of the research questions; there is a wide array of possible research questions relating to a research problem, and focusing on a narrower subset of questions is necessary to avoid ending up with a work of gigantic proportions.

To provide a general basis for the analysis, a *fundamental study* of the standards of the computer/networking area is done. For the more specific research questions, three case studies are carried out. The topics of these studies are chosen for their ability to address the issues in the questions. The *research design* and *method* forming the basis of this process is described in its own separate chapter.

The *case studies* themselves are described in separate case reports, containing descriptions of the cases plus sub-conclusions containing the findings relevant to the research problem of this project.

The findings in the work concerning research questions and cases are analysed in the context of a selected body of *theory*. These theoretical concepts mainly come from the field of standardisation economics. As is the case for the methodological considerations, the choice of theory is described in a separate chapter.

The above disciplines are followed by a *synthesis* of case study findings and theoretical concepts. This is the part of the project, where all the preceding exercises are joined into a body of well-founded knowledge. The essence of the synthesis and sub-conclusions forms the *conclusion* of the project. Here, the research questions are answered by the analysis of the report, and particularly important findings are emphasised.

In the chapter containing *discussion* and *outlook*, the approach of this project is criticized. Also, the models developed for the purpose of describing the convergence landscape are evaluated. To round off the work, the *outlook* section puts the whole work in a relevant context and identifies relevant topics of further research.

1.7. Assumptions and background

In my academic work, I involve primarily objective facts, but probably also – to some extent - subjective elements. The objective elements are comfortably transparent in the sense, that they need no justification or validation. Their objectiveness leaves them open for criticism and facilitates any possible necessary falsification.

I strive only to operate with subjective elements to the extent that they can be justified by common sense or acknowledged through observation. Apart from those subjective elements explicitly presented, it is however likely, that I due to my own idiosyncratic inclinations apply a number of assumptions of a subjective nature to my work.

In order to identify these assumptions and thus eliminate the threat of bias in my work posed by their obscurity, this section presents the inclinations and assumptions of mine, which I have identified during my work:

I tend to believe, that if only the appropriate hard- and software is available – plus access to the necessary infrastructure, then all relevant forms of infocom products and services *will* emerge. They will not emerge by themselves, but if individuals, small and large companies as well as other types of organisations have access to the necessary infocom components, all needs will be served, and the users will select those, which prove most useful. I realize that there are other forces at play here; many powerful players are not particularly interested in the common benefit, but focus on maximizing their profit. The latter is perfectly understandable and acceptable, but unless governments take this aspect into account, a fertile environment for new products and services will not emerge.

I agree with the widespread opinion that there actually *is* a faster rate of innovation on the Internet compared to TV and telephony - e.g. exemplified by the remark:

*“Characterised by an unprecedented growth rate (doubling its number of users every year), the Internet has started to influence a number of economic sectors, with the emergence of a fast-growing electronic-commerce economy.”*²⁵ In addition, I assume that Moore’s Law (that processing power is doubled over a period of 18 months) is a fair estimate of the computer/networking area’s speed of development.

Furthermore, I have believed prior to this work, that the underlying technology of the computer/networking area in many important ways is superior to that of the other converging areas – a belief that is characteristic of the research questions and which is sought justified in the analysis.

²⁵ The European Commission, 1997, p.6.

With my inclination to the Economics of Standardisation, I focus on the positive feedback mechanism in the adoption process (described by W. Brian Arthur, presented in the Feedback and Externalities section of the Theory chapter). A secondary effect of this inclination is my belief, that the Windows computer will be the platform of the foreseeable future due to its current wide adoption compared to competing systems such as Linux and Macintosh.

Having presented these personal tendencies, it is my hope and belief that they – when appearing in noticeable forms in the following chapters – are well explained and justified.

2. Academic Background

An analysis of the convergence of television and computer/networking can be carried out from a number of starting points. Especially when it comes to the academic tradition underlying the analysis, perspectives and approaches are plentiful. This chapter serves to present a number of possible academic perspectives and describe, where in this landscape this particular work is located, and to point out relevant projects and research communities.

This chapter refers to a number of findings and conclusions in this dissertation, but should – in spite of its early placement in this dissertation – not be seen as an introduction to the research problem.

2.1. Three main perspectives

The possible angles of analysis on converging television and computer/networking are numerous, and so are the viewpoints on how these angles of attack can be classified. In this chapter, three different perspectives on convergence are defined. The distinction between the three perspectives is not inspired by any established classification of research, but rather a result of a common-sense interpretation of the different ways in which research in electronic information and communication is conducted. The chapter defines three main research perspectives and – within the perspective of this particular dissertation - describes the relevant approaches, organizations and current projects within these perspectives

The three perspectives are:

- A purely technical perspective
- A techno-economic perspective
- A media or mass communication perspective.

Among these, the purely technical perspective is of limited importance, and mainly serves in supporting the core of this work. The techno-economic perspective, by contrast, is very central and supplies the bulk of the theoretic foundation, focusing on the interplay between technical properties and economic influences, especially relevant in relation to the market's selection and adoption of compatibility standards. The media or mass communication perspective is not involved to any considerable extent. The degree, to which the latter two perspectives are used, is reflected in the theory chapter of this dissertation, where the main part consists of theoretic concepts coming from the economics of standardization and innovation economies, while the media or mass communication perspectives play minor roles.

2.1.1. The technical perspective

One perspective on the convergence of electronic information and communication often applied by engineers and natural scientists is a purely technical one. This perspective is concerned with the workings of technology out of context with the surrounding environment – i.e. without caring about e.g. societal or economic implications of the technology.

An example of a theory from within this perspective is the OSI reference model of computer networks²⁶. This and related theories and models, however, do not account for the workings of markets, the preferences of consumers or the business potential of information and communication phenomena. Instead, they go into much – and for the purpose of this PhD-project, unnecessary – detail on low-level technical issues, thus having their explanatory and analytical strengths far from this project's focus of interplay between technology and economy. Thus, though obviously necessary in many circumstances, this perspective has little part in this work, the aim not being to develop technical solutions to information or communication needs.

Some of the EU IST projects mentioned later in this chapter are of such mainly technical nature. This is the case for e.g. the HOME-PLANET and HISCORE projects mentioned later in this chapter. Here, this PhD-project can contribute with an economic and to some extent societal angle on the issues addressed in these projects.

2.1.2. The media or mass communication perspective

The tradition of media or mass communication research is quite focused on the content of information and communication, a topic that is very central to the convergence view of this PhD-project. In this project, convergence is not merely a question of the border between television and computer appliances becoming blurred. Neither is it only about the infrastructures, which facilitate the information and communication. It is also a question of the content, a view that is subject to attention not only in this dissertation's "Hybrid Communication and Information" case study, but also in the Modality case study. While not having contributed to the core theoretical framework of this project, the media and mass communication perspective has nevertheless been a considerable source of inspiration.

This perspective is represented by communities such as IAMCR²⁷ (globally), ECCR²⁸ (on an European level) as well as a number of national communities. This perspective has become increasingly important in the once mainly technical area of research in computers and information technology.

²⁶ Described further on page 5.

²⁷ Online reference: <http://www.humfak.auc.dk/iamcr/> - link active per 030328

²⁸ Online reference: <http://home.pi.be/eccr/> - link active per 030328

Often focusing on human and societal issues rather than software and hardware, this perspective is an important part of the current research on convergence. One of the more recent theories from this domain – the Media Richness Theory – mentioned on page 95 - is an example of a theory, which has many useful applications. Also, the derived issues of interest of such a theory – e.g. the regulatory and legislative perspectives - it has in common with this PhD-project.

However, for the purpose of this project, neither the Media Richness Theory nor other interesting theories from the media or mass communication perspective have been applied to the analysis of convergence. This is mainly due to a level of detail in issues, which are not particularly well suited for the more techno-economic approach of this project.

Had the intentions of this project been different, this body of theory could well have formed the backbone of the theoretical framework. However, with the mission of conducting an analysis more within the techno-economic field, the media and mass communication theories have found use mainly as sources of inspiration – for example in the development of this project's taxonomy on pages 101ff. With the intention of this project being to take off with an investigation of the flexibility issues of converging information and communication, the theoretical basis must be of a nature, which has more explanatory power in the area of technical and economic flexibility – being able to explain e.g. the ways in which an appliance can be flexible and adaptable.

2.1.3. The techno-economic perspective

The third perspective, here defined as the techno-economic one, is the one central to this PhD-project. It is primarily concerned with the interplay between technology and economy. This, however, spawns a multitude of additional perspectives, among which some of the more important ones – which are at the fringes of this project's topic - are those of legislation and regulation also typical to the media or mass communication perspective described above.

The techno-economic area is at the very core of this dissertation. Particularly the fields of economics of standardization²⁹ and to some extent the economics of innovation³⁰ have been important sources of theory, perspectives and inspiration. This is due to the focus of this project, which is on the systems or sectors (terms defined on page 88f) of television and computer/networking, which are in a process of convergence. Here, the mission of this project is to identify issues in the interplay between technology and economy, which shape the convergence process.

²⁹ Described in detail on pp. 5ff

³⁰ Further described on pp. 5ff

2.2. Related Research Communities

In the techno-economic research domain described above, there are two main bodies of work relevant to this PhD-project. Firstly, the academic work on economics of standardization has provided the core of the theory apparatus applied. While this research branch is not concerned with convergence per se, many of the standardization economists who provide the theoretical framework of this thesis have contributed to the understanding, analysis and forecasting of the convergence process.

Secondly, there are a number of ongoing research and development projects that are relevant to the more practical portions of this PhD-project. Among the European ones, a considerable number are funded by the European Commissions 6th framework on Information Society Technologies. A selection of these – those, which are related to this project's topic – are presented later in this chapter. Some of these have a techno-economic perspective such as this project, while others are of a primarily technical nature.

From the techno-economic field, a number of research communities and individuals have particular relevance to this PhD-project. Some carry out research very similar to that of this project, some are less directly relevant, but nevertheless have contributed to the theoretic framework or inspired the concepts and perspectives of this project. A presentation of the most important among these communities is given in the following paragraphs.

Many of the relevant research communities (e.g. EAP and eLab presented later in this chapter) are of an economic background. Therefore, this project's relevance in relation to such research communities primarily consists of the applied technical perspectives and the thereof derived findings. In other words, this project sheds light inside some of the "black boxes" which are result of technical complexity.

2.2.1. ITC

One of the research communities probably most relevant to this PhD-project is the program on Internet & Telecoms Convergence (ITC)³¹ at Massachusetts Institute of Technology (MIT). Director of the program is David Clark, one of the authors of "End-to-End Arguments in System Design"³², an important paper advocating the principle of having functionality at the end points of information and communication systems.

³¹ Online reference: <http://itc.mit.edu/itc/> - link active per 030224

³² Saltzer, Reed and Clark, 1984.

This PhD-project having appliances and applications as one of the core focus areas³³, there are a number of perspectives in common between ITC and this project. ITC focuses on modularity, hereby stepping away from the traditional understanding of the PC as a complete appliance in a grey box. Modularity is also seen as crucial in this project when comparing the television and computer/networking appliances, e.g. in the TVPC case study at page 169ff. In its definition of its research area, ITC furthermore points out the importance of interfacing the various modules, thus accentuating the importance of standardization, which is the main theoretic perspective of this PhD-project. Yet another similarity between the perspectives of ITC and this project is David Clark's emphasis on open standards as enablers of modularity and hence of technical progress³⁴.

Also from a more business-related perspective, there are similarities between ITC and this project. The attention to cost-effectiveness of emerging technologies, mentioned on ITC's "Research" web page³⁵ could well result in considerations similar to those of this work – especially in the "Hybrid Information and Communication" case study, where the relevant casting scopes as well as the appropriateness of particular forms of information on particular types of networks are discussed. Likewise, the difference in business strategies among incumbents and entrants relate to the findings of this project in the area of entry barriers to content providers as described on page 233f.

Perhaps of the closest relevance to this PhD-project among the members of this research community are the works of aforementioned David Clark. In later articles, he focuses on the "tussles" in Internet development³⁶. These tussles are scenarios where different stakeholders desire different solutions. This is closely related to the standard selection and adoption processes, which are central to this PhD-project – though Clark involves many other incentives than purely technical and economic ones, which are the main focus of this project.

Clark's focus is also on flexibility and adaptability, though formulated alternatively. Clark claims³⁷ that openness to innovation – e.g. by allowing the deployment of new applications and new uses – perhaps is the Internet's most critical success factor. This "openness" has a close resemblance to the flexibility and adaptability as success criteria of the Internet, which is at the core of this PhD project's focus.

Another important parallel between the end-to-end argument and the findings of this project is the similarity between a network and a computer composed of hard- and

³³ See e.g. <http://itc.mit.edu/itel/research.html> (online reference - link active per 030117)

³⁴ This similarity can be observed in e.g. Clark et.al. 2002.

³⁵ Online reference: <http://itc.mit.edu/itel/research.html> - link active per 030117

³⁶ Clark et.al. 2002.

³⁷ Clark et.al. 2002, p.7.

software. Reed, Saltzer and Clark³⁸ point out that the end-to-end argument also applies in the case of the RISC processor architecture. Taken a bit further, the end-to-end argument is also supported by this project's findings on the functionalities of hard- and software in the TVPC case study (pages 174f and 200f): The more functionalities are taken care of by software rather than hardware, the more flexible the appliance is. One could say that the recommendation of "dumb networks and smart terminals" is reflected in the sentence: "let software, not hardware do the work".

Also in another area, the commonalities between the end-to-end argument and the considerations of this PhD-project are interesting. In this project's Information and Communication Taxonomy, two dimensions are presented, which are addressed by the early article on the end-to-end argument³⁹. In their article, the authors point out situations where the end-to-end argument applies in an especially strong form: packet voice communications. It is argued, that the delay caused by low-level reliability measures will impose delays, which disrupt the communication. This consideration can be viewed in the light of the taxonomy, as the dimension of time (on page 116) accounts for situations, where this delay is problematic: it is so in real-time communication, but not when consuming stored information. Secondly, the level of interactivity⁴⁰ also has to do with this particular aspect of the end-to-end argument, as the "redundancy" and "error correction"⁴¹ – which are related to the option of interactivity as formulated in the taxonomy – allow for a repetition of the information lost by errors.

2.2.1.1. More on the end-to-end argument

As mentioned above, the End-to-End argument proposed by Saltzer, Reed and Clark⁴² has been an important guideline for Internet development. The core of the argument is placing functionality in the end nodes instead of in the network itself. This has proven useful in computer networks because of the distributed intelligence, which is embedded in the appliances (the PCs). A widespread (and probably correct, though simplified) interpretation of the end-to-end argument is the recommendation of having "dumb" networks and "intelligent" terminals.

When comparing computer/networking (e.g. embodied by the Internet) with television, one is struck by the difference in intelligence embedded in the terminals: Computers have much processing power, while TV sets have little or none. Having defined the Internet as a system of dumb networks and smart terminals, it is thus

³⁸ In Saltzer, Reed and Clark, 1984 as well as Reed, Saltzer and Clark 1998.

³⁹ Saltzer, Reed and Clark, 1984, p. 6-7.

⁴⁰ as described on p. 5.

⁴¹ as formulated by Saltzer, Reed and Clark, 1984, p.6.

⁴² Saltzer, Reed and Clark, 1984.

tempting to apply the inverse interpretation to the television system: labelling it as a smart network with dumb terminals.

The straightforwardness of this statement is due mainly to the intelligence of computers - they are the smartest terminals, average households have. And, admittedly, the TV set is a very dumb appliance. This contrast is, however not reflected (neither directly or inversely) in the infrastructures, which carry the information and communication of the two systems. For this to be the case, the television networks would have to be “intelligent” or “smart”.

Bluntly put, the television system is simply plain dumb. Its network is even so dumb, that all who is connected receive all information, even that, which isn’t intended for them (an example of this is the Danish “TeVeFonen” real estate brokerage service mentioned on page 386f in the appendix of this dissertation. Another example is pay-TV-channels: everyone who is connected to the network, be it terrestrial, satellite or cable receives these channels, only they are scrambled in order for the non-subscribers to be unable to view them. The only obvious intelligence or smartness of the television system lies with the content suppliers, who generate shows, movies etc with complex equipment and processes.

It is tempting to interpret the end-to-end argument as an advocacy of dumb networks with smart terminals. But this is hardly the main point. Rather, the end-to-end argument is a recommendation of general-purposeness in networks – keeping the network able to deliver all kinds of traffic. This interpretation is supported by a statement by David Clark⁴³, who points out that “If the core of the network has been tailored to one specific application, this may inhibit the deployment of other applications”.

This implies that the distinction by Reed et. al. rather is between “general- vs. special-purpose networks” than one between “dumb vs. smart networks”. This, on the other hand is a very central observation, quite relevant to the comparison and analysis carried out in this PhD-project. The general-purposeness of the Internet is one of the main issues in this dissertation’s “Hybrid Communication and Information Case Study”, and this is a property of the Internet without which many of the flexibility benefits pointed out would be absent.

The recent developments of the Internet protocol (IP version 6) are often criticized for being anti-end-to-end. Especially multicasting and QoS (quality of service) are seen as features, which impose demands of network-based functionality on the Internet. In this dissertation, multicasting is presented as an important (and necessary) feature if traditional television content should be distributed via the Internet as described on page 258. This can be interpreted as an anti end-to-end viewpoint, but this is not the

⁴³ Clark et.al. 2002, p.8.

case. This project does not as such recommend the transition to Internet based television content distribution, but acknowledges the fact, that without an appropriate solution – among which multicasting seems a good bid – the bandwidth consumption would be enormous. However, though the most obvious candidates for effectively functioning multicasting indeed imply network based functionalities, multicasting need not necessarily imply a step away from the end-to-end principle (as indicated by Clark⁴⁴). Additionally, this dissertation describes a realistic alternative where different types of content are distributed along each their own “dumb” network (exemplified by the TVBoost proof-of-concept prototype), thus retaining simplicity in each of the involved networks.

In later papers⁴⁵, David Clark accordingly softens his view on the necessity of a purist end-to-end approach. In the light of changing requirements (a. o. avoidance of spam mail, protection of intellectual property rights, protection of minors against unsuitable content), he – while not at all abandoning the end-to-end argument – accounts for a number of interests pulling in a different direction. This view – and the relative openness to implementation of network functionalities - is not necessarily shared by Saltzer and Reed (the two co-authors of the original end-to-end article). In a recent paper by all three authors⁴⁶, it is pointed out, that while a few examples of the end-to-end argument being counter-productive actually exist, they are very few.

The end-to-end argument – the original version of it as well as the revised viewpoints put forward by a.o. David Clark - accentuates the importance of this PhD-project’s research problem. The works of Clark, Reed et.al. are highly related to the area of investigation of this project, and many of its findings can benefit from being viewed in the light not only of the end-to-end argument, but also the later articles by David Clark. The end-to-end argument is applicable to all three case studies of this thesis. Obvious parallels can be observed in the “Hybrid Communication and Information Case Study” of this dissertation, which proposes the use of the computer’s distributed intelligence for combining the content of *two* dumb(ish) networks. In the “Modality Case Study” study, the distributed intelligence proved crucial in order to display any form of stereoscopic content. The “TVPC Case Study” has a clear parallel to the end-to-end argument, as it points out that software based functionalities rather than hardware based ones lead to greater flexibility and adaptability.

⁴⁴ Clark et.al. 2002, p.9.

⁴⁵ E.g. Blumenthal and Clark, 2001

⁴⁶ Reed, Saltzer and Clark 1998.

2.2.2. EAP

A more economic and regulatory (and thus less technical) perspective is applied by the EAP group at Haas, Berkeley⁴⁷. Its faculty counts members⁴⁸ such as Carl Shapiro⁴⁹, David Teece⁵⁰, Joseph Farrell⁵¹ and Michael L. Katz⁵², people who have contributed significantly to the theoretic foundation of this project. Though they also perform teaching as well as government services⁵³, perhaps the most prominent achievement of EAP is the book “Information Rules” by Carl Shapiro and Hal R. Varian.

This book sums up most of the trends in standardization economy for the last 30 years. It touches upon a number of the topics of this PhD-project, e.g. the importance of flexibility in appliances as well as the chicken-and-egg problem⁵⁴. Published as late as in 1999, this book has not by itself been of any particular inspiration to this project, but the articles upon which it based⁵⁵, it has in common with this project. While clearly having a more economic approach - giving recommendations of strategic and tactical choices in standards wars - than this project, Information Rules presents similar findings. Though the authors demonstrate a considerable technical knowledge, the findings of this PhD-project may provide even further insight into the workings of appliances and infrastructures – issues, which in Information Rules tend to be regarded as “black boxes”.

2.2.3. Vanderbilt University's eLab

A research community, which focuses on more business-related issues – but nevertheless has provided relevant input to this project - is Vanderbilt University's eLab⁵⁶. It was founded in 1994 by Professors Donna L. Hoffman and Thomas P. Novak, and claims to be the nation's first academic research center dedicated to the study of the Internet⁵⁷. Thus, it has a more micro economic approach than this PhD-project. In spite of the different focus, the research of this community is relevant to this PhD-project in a number of ways.

⁴⁷ I.e. The Economic Analysis & Policy Group at Haas School of Business at the University of California at Berkeley

⁴⁸ According to fodnote: <http://www.haas.berkeley.edu/faculty/teece.html> and <http://www.haas.berkeley.edu/groups/eap/faculty.html> (online references - links active per 030122)

⁴⁹ Often referred to in this dissertation – e.g. on page 5.

⁵⁰ Referred to on page 5.

⁵¹ Rerferred to on page 5.

⁵² Referred to on page 5.

⁵³ According to <http://www.haas.berkeley.edu/groups/eap/about.html> (online reference - link active per 030302).

⁵⁴ Shapiro and Varian 1999, p. 189.

⁵⁵ By the aforementioned faculty members plus others such as Liebowitz, Margolis and W. Brian Arthur.

⁵⁶ <http://elab.vanderbilt.edu/> - link active per 030217.

⁵⁷ According to <http://elab.vanderbilt.edu/about/mission/index.htm>.

Especially the taxonomy in "Marketing in Hypermedia Computer-Mediated Environments: Conceptual Foundations"⁵⁸, has been a major source of inspiration in the development of this thesis' taxonomy, as it is a very useful descriptive tool in relation to e-commerce as well as the Internet in general.

To a considerable extent focusing on modality as an important competitive parameter, eLab has a number of further topics in common with this PhD-project. Both the aforementioned work and the later "Impact of 3-D Advertising on Product Knowledge, Brand Attitude, and Purchase Intention: The Mediating Role of Presence"⁵⁹ demonstrate the commonalities. As is the case with EAP, this PhD-project can supplement and inspire research of eLab's kind through a deeper understanding of and attention to the technicalities of the convergence process.

2.2.4. Further relevant research communities, individuals and publications

In addition to the above mentioned research communities, a number of individuals and informal groups work with issues related to this project. Other research communities have less obvious relation to this PhD-project than the above mentioned. These groups and individuals are described in the following paragraphs.

David Reed, co-author of "End-to-End Arguments in System Design", comments on the development of the Internet on his website, SATN.org⁶⁰, which he maintains with Bob Frankston and Dan Bricklin. This is not a research community as such, but still – especially due to Reed's status as an Internet pioneer – an important source of commentaries, essays, a weblog, etc. The focus tends towards the intersection between regulation, standardization and policy based on a technical knowledge of computer networks and telephony. Though more journalistic than scientific, it is an interesting forum that has several issues in common with this PhD-project.

Thomas P. Hughes, Professor Emeritus at University of Pennsylvania⁶¹, who has provided the definition of systems used in this dissertation (see page 89), is a technology historian. It has not been possible to link him to any particular research community – apparently; he has created his own "school" of thinking around the notion of "Large Technological Systems". Lately, he has done several publications with researchers from Max-Planck-Institut für Gesellschaftsforschung, however on issues not related to this PhD-project. His earlier work⁶² in the 1980s with the Social Constructivist (SCOT) community has more relevance to this project. Though Hughes' perspective on technological systems has been applied to the convergence

⁵⁸ Hoffman and Novak, 1995.

⁵⁹ Li et.al. 2002.

⁶⁰ <http://www.satn.org/> - link active per 030115.

⁶¹ <http://www.alteich.com/links/hughes.htm> - link active per 030211.

⁶² Hughes, 1989.

process in this project, the SCOT theory has not. Though in many aspects certainly relevant with its focus on the users' interpretation of the technology, it has not been seen as appropriate for this project, considering its techno-centric focus on the capabilities of appliances, content and infrastructures.

One of the early standardization economists, Paul A. David, at Stanford Institute for Economic Policy Research⁶³ (SIEPR) is involved in research with some relevance to this PhD-project. He heads the "Economic Organization and Viability of Open Source Software Project"⁶⁴, which is conducted in cooperation with researchers from SPRU (formerly The Science Policy Research Unit) at University of Sussex, UK. Though not exactly on topic, the open source considerations still are important in relation to this PhD-project. This project has not gone into particular detail on open source issues, but further research topics could well focus on open source software in networks as well as appliances. The research partner in the SIEPR open source project, SPRU, is also involved in related research, though with a rather regulatory focus, compared to this PhD-project. Among its earlier faculty members are Robin Mansell, now at London School of Economics and Keith Pavitt⁶⁵. The most interesting community – from a convergence point of view – at SPRU is probably the Information Networks and Knowledge Research Centre⁶⁶, whose director, W Edward Steinmueller, is affiliated to the aforementioned open source project at SIEPR.

Having a more regulatory focus than this PhD-project, organisations like the WDR (World Dialogue on Regulation for Network Economies) is an example of a community⁶⁷, which – while having a different focus – could benefit from the techno-economic considerations of this project. With its intention of contributing to future-proof regulation which stimulates and facilitates well-functioning future networks and infrastructures⁶⁸, such communities need qualified suggestions of future information and communication scenarios as well as an analysis of the determinants of this development – suggestions and explanations which are provided in this dissertation.

In addition to the rather academic work of universities, a number of R&D projects are relevant to this PhD-project. Many take place in private companies and consortia, some are funded by governments or regional authorities. A topical and local example of such projects is the Crossroads Copenhagen Project B: Situation-based Mobile

⁶³ <http://siepr.stanford.edu/home.html> - link active per 030212.

⁶⁴ http://siepr.stanford.edu/programs/OpenSoftware_David/OS_Project_Funded_Announcmt.htm - link active per 030212

⁶⁵ Mentioned on page 5.

⁶⁶ <http://www.sussex.ac.uk/spru/ink/index.html> - link active per 030212.

⁶⁷ WDR counts among its advisors and research programme leaders researchers like William Melody (Technical University of Delft, the Netherlands and Center for Tele-Information at the Technical University of Denmark), as well as aforementioned Robin Mansell (London School of Economics) and Nicholas Garnham (CCIS, University of Westminster, UK).

⁶⁸ According to <http://regulateonline.org/whywdr.htm> - link active 030212.

Services⁶⁹ focuses on the use of heterogeneous networks in combination for delivery of different types of content – thus having a considerable relation to the “Hybrid Information and Communication case study” of this PhD-project. Another large body of work relevant to this project can be found among the EU IST projects, which are presented in the following paragraphs.

2.2.5. Projects under the European Commission

One of the major inspirations of this PhD-project is the European Commission’s Green Paper on convergence⁷⁰. It was published in 1997, in advance of the 5th framework programme⁷¹ running from 1998-2002. Since then, the 6th framework programme is well underway, supporting a wide array of IST (Information Society Technologies) projects⁷², some of which have much in common with the research carried out in this project.

The projects mentioned below all aim at doing research and/or development in fields that are relevant to this PhD-project. While some are relevant only to a specific and limited area, others have broader relevance. It is interesting to note, how the presented projects adhere to the particular case studies carried out in this project – a tendency, which is emphasized in the following by grouping the IST projects according to this project’s case studies.

The following pages present a selection of the 6th framework IST projects, containing those, which have issues in common with this PhD-project. The commonalities do not extend further than a shared focus, that is, the IST projects have not been analyzed further in this PhD-project, and neither has this PhD-project provided any input to the IST projects.

2.2.5.1. TVPC

The TVPC case study focuses on the use of computers in the roles of traditional television appliances – e.g. TV sets, VCRs and set-top boxes. This case study is related to the “interactivity promise” described on page 5. One of the main problems of using computers for viewing and recording purposes is the relative difficulty of operation. If the computer should be a realistic appliance for traditional television purposes, there is a need for systems and applications, which work with greater ease than those of today. The use of computers for television purposes is subject to the

⁶⁹ http://www.crossroadscopenhagen.com/project_b.htm - link active per 030302.

⁷⁰ The European Commission, 1997.

⁷¹ “European research activities are structured around consecutive four-year programmes, or so-called Framework Programmes.”, ISTweb homepage: <http://www.cordis.lu/ist/>.

⁷² In the following, to minimize the risk of confusion, the Commission’s projects are referred to by their names or as projects, while the PhD-project leading to this dissertation is referred to as “this PhD-project” or sometimes, when the meaning is obvious, simply “this project”.

attention of a number of EU IST projects presented below. They are relevant to the work in this PhD-project, as they represent a number of actual solutions, however too late in time or too undeveloped to be included in the case studies. The relevance could well go in the opposite direction, as the investigation of the workings of markets and standards could benefit projects such as the ones mentioned below.

The PiSTE project⁷³ attempts to build a TV system integrating computer-generated models with live video using established standards. Being located in the intersection between television and computers, focusing on delivering choice to the user and encompassing both the production side and end-user terminal, this project is a candidate for delivering the “interoperability promise” defined in this PhD-project (on page 3). Such a project could well benefit from the findings related to the interoperability promise – especially in the area of appliances, their capabilities and limitations.

SAMBITS⁷⁴ develops a system for DVB broadcast with complementary Internet services and vice versa. Among its specific aims is the development of terminal equipment with the ability to receive and display both DVB broadcast and Internet content in an integrated fashion. This objective is highly related to the focus of this PhD-project, especially the TVPC case study, which describes and analyses the requirements and possibilities of such appliances.

The aim of the GMF for ITV⁷⁵ project is to provide a generic platform for development of future DVB-MHP⁷⁶ services on set-top boxes as well as on PCs. Among the project's goals are the extension of the DVB-MHP capabilities and provision of a generic tool set for expansion of the usability and quality of interactive services. With its focus on set-top-boxes as well as PCs, the project could benefit from the analysis of the capabilities and potential of PCs for television purposes, which is carried out in this PhD-project.

Focusing on an in-home digital network, based on the IEEE1394 (a.k.a. FireWire) bus, the HOME-PLANET⁷⁷ project has a very standard-centric focus. Furthermore being concerned with the interfacing of appliances, it is highly topical to this PhD-project - and vice versa. Especially this PhD-project's TVPC study has common focal points with HOME-PLANET, however the apparently purely technical focus of the latter suggests, that it could benefit from many of the standardization-economic considerations of this PhD-project.

⁷³ <http://piste.intranet.gr/overview.htm> (link active per 030211)

⁷⁴ <http://www.irt.de/sambits/> (link active per 030214)

⁷⁵ <http://www.gmf4itv.org/> (link active per 030211)

⁷⁶ Further described on page 5

⁷⁷ http://dbs.cordis.lu/fep-cgi/srchidadb?ACTION=D&SESSION=211952003-2-18&DOC=1&TBL=EN_PROJ&RCN=EP_RCN_A:57830&CALLER=PROJ_IST (link active per 030211)

2.2.5.2. Modality

The modality case study of this PhD-project investigates and compares the ability of various appliances of displaying stereoscopic content. An important issue in this case study is the chances of stereoscopic television content becoming a widespread phenomenon. Here, a major issue is the chicken-and-egg problem of lacking incentive to produce content as long as no suitable appliance exists and vice versa. A number of EU IST projects address this topic as well as a number of other issues relating to stereoscopy. They are interesting in relation to this project, as they present bids for solutions as well as new systems and methods, that in time could be interesting topics for further research along the lines of this PhD-project.

The ATTEST⁷⁸ project designs a modular 3D-TV system encompassing the whole broadcast chain - from the camera to the end user's appliance. One of the main concepts of ATTEST is the separation into 2D picture and corresponding depth information, whereby backwards compatibility with existing TV systems are said to be achieved. Hereby, one of the major obstacles to development identified in this PhD-project, namely that of the chicken-and-egg problem, can be overcome. ATTEST also develops 2D-to-3D conversion tools, hereby attempting to help the lack of 3D-content. Thus having identified the same obstacle as this PhD-project, many of the projects other considerations could as well be relevant to ATTEST.

The objective of the MIAMM⁷⁹ project is to develop new concepts and techniques in multimodal man-machine dialogues. The main focus is haptic (via the sense of touch) in- and output. Though this project is more focused on multi-modality in *input* than this PhD-project, the findings concerning the chicken-and-egg problem of this PhD-project could be highly relevant to MIAMM, especially when assessing the chances of market success of a new in- or output device or a new multi-modal service.

The MetaVision⁸⁰ project is dedicated to the generation of a demonstration production chain encompassing capturing, production, storage as well as distribution. This value chain focus is to some extent comparable to the focus of this PhD-project on infrastructure and appliances (where the supply side is subject to less attention). Focusing on benefits such as flexibility in resolution and depth metadata containing 3D-information, MetaVision touches upon the topics covered in this PhD-project's modality study. Furthermore, with its focus on incorporation of e.g. HTML and XML in the broadcast, MetaVision also shares focus with the "hybrid communication and information" case study.

⁷⁸ http://dbs.cordis.lu/fep-cgi/srchidadb?ACTION=D&SESSION=197662003-2-14&DOC=1&TBL=EN_PROJ&RCN=EP_RCN_A:62861&CALLER=PROJ_IST (link active per 030214)

⁷⁹ <http://www.loria.fr/projets/MIAMM/presentation.html> (link active per 030211)

⁸⁰ <http://www.ist-metavision.com/> (link active per 030211)

The HISCORE⁸¹ project develops a stereoscopic colour video camera. Though the project apparently is a primarily technical one, it could benefit from the considerations of this PhD-project - especially the discussions on the possibilities of increased modality in future content and appliances.

2.2.5.3. Hybrid Communication and Information

One of the main issues in this PhD-project's "Hybrid Communication and Information" case study is the use of different types of networks for different types of information and communication. The study suggests a combination of the Internet and the traditional television networks for different services – e.g. a broadcast signal via the television network and supplementary information via the Internet. The case study also describes, how issues such as "scope of interest" and "importance of immediacy" (described on page 228) influence the choice of distribution channel. This perspective it shares with a number of IST projects presented in the following. These projects explore alternative organisations and distribution methods, and have considerations similar to those of this PhD-project. Some of them are quite technical by nature, and can benefit from the market and standards considerations of this project, while those more concerned with the business side of things accordingly can benefit from this project's technical areas.

The PROXITV project⁸² aims at developing a solution for delivering television over ADSL. While primarily focusing on technical issues, the PROXITV project is also concerned with ensuring functional payment schemes as well as incorporating all major formats. Especially in the latter area, the analysis of standards and standardization issues in this PhD-project are relevant, as the agendas and interests underlying the standardization choices and processes are pinpointed.

The OLYMPIC⁸³ project attempts to develop an Internet based streaming real-time service, bringing live video to smaller special interest groups. The purpose of this project is very much in line with the scope-of-interest/importance of immediacy considerations of this PhD-project. Though the OLYMPIC project obviously already have considered these aspects of content (as it suggests the Internet for content with a narrow scope of interest), it could still benefit from the related discussions of e.g. the appropriate infrastructures and appliances for particular types of information and communication.

⁸¹ http://dbs.cordis.lu/fep-cgi/srchidadb?ACTION=D&SESSION=43552003-2-18&DOC=1&TBL=EN_PROJ&RCN=EP_RCN_A:54461&CALLER=PROJ_IST (link active per 030211)

⁸² <http://www.istproject.com/proxiv/summary.html#t> (link active per 030211)

⁸³ http://dbs.cordis.lu/fep-cgi/srchidadb?ACTION=D&SESSION=250582003-2-14&DOC=3&TBL=EN_PROJ&RCN=EP_RCN_A:59080&CALLER=PROJ_IST (link active per 030214)

The GMF for ITV project mentioned earlier under the TVPC case study furthermore focuses on the integration of linear and non-linear content (e.g. live video and HTML data). The "hybrid communication" studies carried out in this PhD-project has significant relevance in this area, as it focuses on the appropriateness of infrastructure for particular types of content. Among these types are defined higher or lesser degrees of "importance of immediacy", a distinction, which corresponds well with the linear/non-linear perspective of the GMF for ITV project.

The NexTV⁸⁴ project focuses at evaluating and analyzing business models for future broadcast scenarios. Expecting interactivity in addition to or in combination with traditional broadcast, the project aims at creating set-ups for verification of the possible business models. NexTV has a very economic angle, as does this PhD-project. Likewise, both projects also have technical angles. The main difference in the angle of attack is, that NexTV primarily focuses on what is economically possible within the technical limits, where this PhD-project rather focuses at technical possibilities in an economic framework. As such, both projects could benefit from each other's findings.

The SAVANT project⁸⁵ will demonstrate how various forms of interrelated multimedia content can be delivered over different (broadcast and telecom) networks. With its focus on the efficient choice of which content to distribute on which network, the SAVANT project has much in common with this PhD-project - especially the "Hybrid Communication and Information" case study, which is concerned with the appropriateness of different forms of content on different infrastructures. SAVANT also takes into account, that the content will be consumed on a variety of different appliances with different capabilities - a topic covered in this PhD-project's TVPC case study. As it also aims at contributing to standards, the SAVANT project might well benefit from many of the standardization-related findings of this PhD-project.

2.3. This PhD-project's relation to the surrounding world

As has been described in this chapter, this PhD-project takes off from a techno-economic perspective. Its chosen topics and angle of attack resembles those of a number of academic communities among which some have a technical focus, while others have more economic or regulatory inclinations.

This PhD-project also has much in common with a number of R&D project under the EU's IST programme. Again, there are different perspectives among these projects, and while this PhD-project's possible contributions to the IST projects in some cases are technical, it could in other cases – when the IST projects have a technical inclination - be of a more economic nature.

⁸⁴ <http://www.extra.research.philips.com/euprojects/nextv/> (link active per 030211)

⁸⁵ <http://www.brunel.ac.uk/project/savant/> (link active per 030211)

3. Research problem

This project is concerned with the coming together of television and computers in the old-fashioned meaning of the word – from back before convergence became a household word. It attempts to explain this process, and to find out what determines the way in which it progresses. The starting point is the definition of the question, which guides the following investigation.

The analysis of the convergence between television and computer/networking⁸⁶ taking place in this PhD-project is guided by a fundamental research problem. This research problem is inspired by the techno-economic considerations that arise when observing the convergence process; considerations, which are concerned with the nature of the process, the crucial influential factors in it as well as the possible outcomes of it.

The starting point in this PhD-project is the very turbulent and dynamic process of change in the landscape of electronic information and communication. Here, it is assumed that, among the systems, technologies, standards, companies, etc. participating in the process, some are better suited for adapting to the changing conditions and requirements than others. Correspondingly, some are better suited for influencing and shaping the convergence process. The ones, which are best suited for change – i.e. the most flexible – will stand a better chance of prevailing in – and contributing to – the future form of electronic communication and information consumption.

The research problem derived from these considerations is formulated as a hypothesis⁸⁷, which postulates a particular strength in flexibility of the computer/networking system and claims, that this strength will give it an advantage in the convergence process.

⁸⁶ The two terms, computer/networking and television systems, encompass the components of the two corresponding sectors with particular focus on their appliances, their infrastructures and the types of content typical to them. This is in accordance with the use of the terms systems and sectors in the definition on page 5 and the surrounding discussion: The three converging areas defined as systems and as sectors, where the system term is used when describing the interplay of components.

⁸⁷ Though the research problem is formulated as a hypothesis, it will not be subject to scrutiny in the traditional positivist fashion – involving the formulation of predictions derived from the hypothesis and measuring whether the predictions actually come true. Such an attempt would be impossible without the opportunity of an ex post analysis of the validity of the postulates of the hypothesis. As the convergence process is an ongoing phenomenon, attempts of supporting or falsifying the hypothesis in this fashion is not possible for the next many years.

The research problem formulated as a hypothesis:

In the convergence between television and computer/networking, the latter exhibits a higher degree of flexibility in appliances and infrastructure. This flexibility gives the computer/networking system an advantage over the television system in its ability to adapt to - and stimulate the development of - new products and services.

Thus, the hypothesis of the research problem states two postulates: firstly, that the computer/networking sector actually is more flexible in key areas⁸⁸ than the television sector, and secondly, that this flexibility advantage actually does makes it more adaptable to the changing conditions.

The reason for the emphasis on flexibility is the assumption, that in times of technological turmoil such as this, one of the most important properties of a particular sector or system (or, for that matter, company, product or service) is the ability to adjust to changing conditions and emerging opportunities. Flexibility is here regarded as an important characteristic when attempting to fulfil the earlier mentioned “promises of convergence”

Flexible: characterized by a ready capability to adapt to new, different, or changing requirements.

Definition 9: Flexibility⁸⁹ (a lexical definition)

To further clarify the definition above, the flexibility issues under investigation in this PhD-project are those that are of a technical (and not. e.g. a business) nature, though also flexibility in organisation – e.g. in standardization processes are relevant. The flexibility characteristics in focus are relevant to e.g. suppliers of new services and appliances as well as the power users, but not to the average end users.

Here, one might argue, that there are other important aspects besides flexibility. E.g. the fact, that the television system is well-established compared to computers and the Internet, might give this particular system an advantage. This is undoubtedly true, and these alternative strengths and weaknesses are also accounted for in this dissertation. However, among the many important aspects, the starting point of this investigation is flexibility, and while this project aims at identifying the existence and the effects of flexibility, less effort is directed towards explicitly proving that flexibility actually is very important compared to other aspects.

⁸⁸ The key areas in particular focus in this PhD-project are appliances, infrastructures and content.

⁸⁹ <http://www.webster.com/cgi-bin/dictionary> (link active per 030130)

Though the approach of comparing flexibility issues in converging television and networking standards at the appliance and infrastructure levels is interesting, the claim that flexibility is important is not novel by itself. The early design principle for the Internet, the “End-to-End Argument in System Design” presented by Saltzer, Reed and Clark⁹⁰ is very focused towards the adaptability and flexibility benefits of such a system. Also later articles by Clark⁹¹ are very occupied with preserving flexibility and adaptability in the Internet.

Shapiro and Varian⁹² also touch upon the flexibility issue, though in a more implicit fashion in the form of a recommendation of smooth migration paths towards future versions of what the authors refer to as “your technology”. This perspective comes from a more business related standpoint than that of this PhD-project. Nevertheless, the necessity of flexibility when offering a smooth migration path also applies on other levels than that of a single product or service, and is thus also relevant in the convergence between television and computer/networking.

Though the later chapters account in detail for the importance of flexibility, a short explanation should be given here. The convergence process is widely expected not only to bring forward a number of new products and services, but also to reveal and accentuate a new mass of possibilities and needs. No matter whether one applies a demand-pull or a technology-push perspective, it is obvious, that a product, company, system or sector which is flexible, i.e. able to accommodate new standards and methods in its operation, stands a better chance of:

a: to adapt to new trends and demands (the ability necessary if one applies a demand-pull perspective)

- as well as

b: to be able to develop and provide novel products and services. (the ability necessary from a technology-push perspective).

Adaptable: capable of being adapted.

Adapt: to make fit (as for a specific or new use or situation) often by modification.

Definition 10: Adaptability⁹³ (a lexical definition).

⁹⁰ Saltzer, Reed and Clark, 1984.

⁹¹ Clark et.al. 2002

⁹² Shapiro and Varian, 1999, p.191.

⁹³ <http://www.webster.com/cgi-bin/dictionary> (link active per 030130)

If, for example, a new standard of picture resolution is introduced, the flexible appliance stands the better chance of being able to incorporate this particular standard. Or, from a demand-pull perspective: if a demand for such higher picture resolution appears, the service providers from the more flexible sector with the more flexible infrastructure stand a better chance of actually providing it.

As the above explanation suggests, this PhD-project examines flexibility issues in the appliances, infrastructures and the content of television and computer/networking. The flexibility benefit of computer/networking is therefore sought among these components; more precisely in the standards, which constitute the infrastructures, appliances and content. Here, not only the standards themselves, but also the standardization procedures can exhibit more or less flexibility and accordingly make for higher or lower adaptability. Here, the development is viewed in terms of economics of standardization – i.e. in the light of e.g. the positive feed-back theory (described on pages 65f), the distinction between hardware-software systems and communication networks (described on pages 73ff) and the possibility of lock-in (described on pages 69f).

One can say that the underlying logic or perspective is that of standards, as they are seen as the building blocks of appliances, infrastructure and content, and the selection and adoption processes that shape the development are standards selection and adoption processes, because most of the components – interfaces, codecs, resolutions etc - which are converging, are defined in terms of standards. The research question can be examined from other perspectives, but – the focus of this PhD-project being a techno-economic one – the perspective here is that of standards.

Being very broad by nature, the hypothesis of the research problem cannot in itself be subject to analysis. Therefore, it is broken up into multiple sets of derived research questions (according to the earlier identified “promises of convergence”), each attacking a specific sub-topic, where the key areas of investigation are defined in more narrow terms. The findings and answers to the research questions in turn serve to support or reject the basic hypothesis.

Besides the research questions, another set of questions; the *Conceptual questions* are posed. Their purpose is to define the *Conceptual framework* of theoretical perspective within which the research questions are analysed. Thus, the whole process of defining the research problem, and posing the relevant conceptual and research questions can be illustrated as follows:

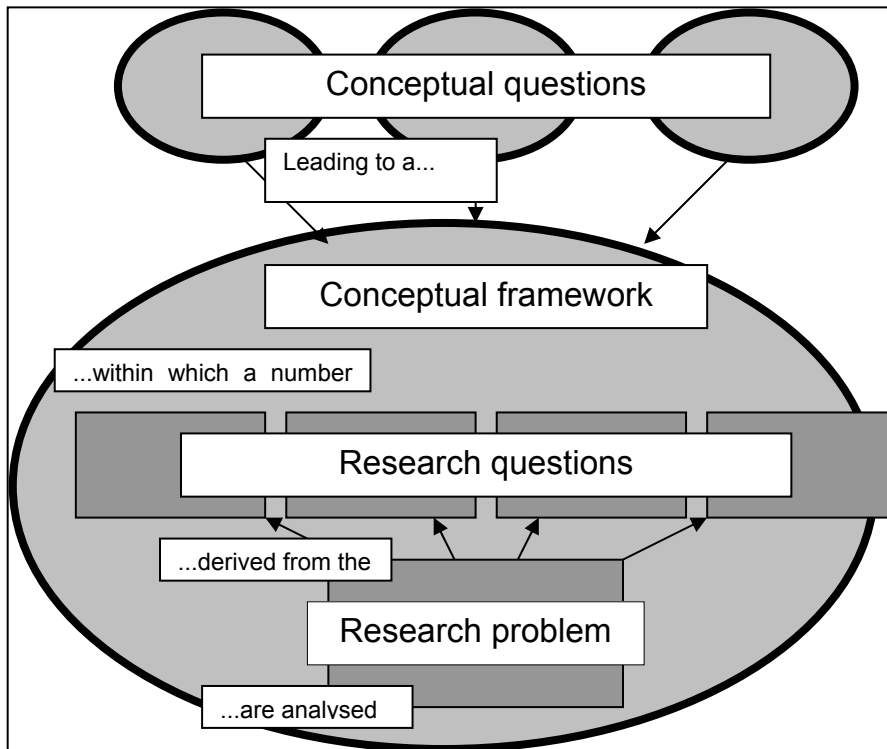


Figure 3: The interrelation between conceptual questions, the conceptual framework, research problem and research questions.

3.1. Conceptual questions

The purpose of this group of questions is to define the framework within which the investigation and analysis is conducted. This is done by asking a number of relevant questions concerning the *nature* of the important topics relevant to this work. The topics involve the process of convergence and the basic properties of information and communication on a level of abstraction reaching beyond household terms such as phone and TV.

The results of defining a conceptual framework might seem less noticeable than the results of asking and answering research questions. Nevertheless, it is a necessary step in the scientific process, as it provides a well-defined framework for the actual analysis – a framework where the central terms are properly defined, and where steps have been taken to ensure, that analysis is not conducted on the basis of an insufficiently developed perspective.

These questions relating to the conceptual framework will primarily be analysed from within the findings of the conceptual study (the Information and Communication

Taxonomy). This study, however, are not limited to explaining this particular category of questions. Also the research questions can benefit from the findings of the conceptual study.

3.1.1. Information and communication characteristics

When examining communication and information consumption in the convergence area, it is necessary to have an overview of the manifestations of the various forms of communication or information. Therefore, one of the first steps in this project is the identification of the different actual forms of infocom, a description of their basic properties and purposes as well as a set of definitions of a number of generic information and communication characteristics.

A manifestation means the actual presence of a form of communication or information consumption. A telephone conversation is an example of a manifestation. The use of IP telephony is a manifestation of the possibility of transmitting real-time voice over computer networks (these opportunities are mapped in the Information and Communication Taxonomy).

Definition 11: A manifestation (a stipulative definition).

Looking at the basic characteristics is useful when for example investigating a well-known communication phenomenon and assessing the practicability of using this phenomenon in another area⁹⁴. But first and foremost, this discipline provides a descriptive model, which serves as a foundation for the further work.

This investigation is guided by the following conceptual questions:

- Which actual forms of infocom can be identified in the three areas?
- Which generic communication and information characteristics can be derived from the actually observed forms of infocom?
- What are the properties of the content of communication or information in the various areas?

These questions are answered in the Information and Communication Taxonomy chapter, where a framework for description and analysis of convergence phenomena is developed.

⁹⁴ A practical example of this is the application of the traditional communication form of voice telephony on the Internet in the form of so-called IP-telephony.

3.1.2. Areas

From the beginning, this project has applied a view of three areas on the convergence process. This means that television, computers/networking and telephony are seen as somehow separate areas that are coming together.

This is the point of departure, as it is a generally accepted view of the ongoing process. There is always the risk, however, that one takes off with a certain set of assumptions that are not suited for gaining an understanding of the topic of investigation. Other areas such as newspapers, cinemas and Hi-Fi could be argued to influence the process of convergence. And the danger is leaving out valid sources of explanations of the process taking place.

The model with three intersecting sets or classes (seen in this work as Figure 1) is often used to show overlaps between various areas in many different fields of research. It is very useful, because it is possible to illustrate in exactly which intersection a particular focus or element is.

When using this particular figure, there is, however, often a risk that one leaves out a fourth or even a fifth relevant set (and hence an important fourth or fifth area), because the graphics works with only three sets. Imagine adding a fourth set to the figure. If all possible intersections should be included, the graphic appearance of the figure would be very complex and quite ugly.

Therefore, it is nearby to focus on three areas only, as it can be illustrated so beautifully. The figure is seductive. One should beware not to leave out something important just to be able to show a neat figure.

Author's comment 1: The risk of the seductive three sets.

A question for the conceptual framework is thus, of which areas are part of the convergence process – i.e. whether television, telephony and computer/networking are in fact the important converging areas. It is not the task of this project to decide whether this is the case – especially as the focus only is on a subset of the converging areas – namely television and computer/networking. Hence, this question will not be answered directly, but is be kept in mind in the various studies of the project – and commented upon in the Discussion chapter.

Another issue is how to denote the converging areas, regardless of which particular areas, one attributes to the convergence process. Therefore, a number of existing considerations concerning how to define such segments of a greater whole are looked

upon. Here, a number of alternative views are considered⁹⁵. This exercise is mainly a theoretical one, which is carried out in relation to the “Economics of Innovation” discussion in the Theory chapter.

Both these considerations are somewhat implicit exercises in the project, and no separate account for the considerations is given.

To sum up, the questions here are:

- How can we define the areas in infocom that are involved in the process referred to as convergence?
- Which areas are relevant considering the focus of the project?

3.2. Research questions

The modelling and casework in this Ph.D. project is determined by the research questions derived from the research problem presented earlier. These questions are sorted in groups according to the main topic, which they address.

Some of the research questions have a quite broad focus, while others are more specifically related to the promises presented in the “Promises of Convergence” section of the Introduction chapter (and hence to the three case studies relating to each promise of convergence).

3.2.1. Broad research questions

First, a set of fundamental research questions is presented in the following. These are questions aiming at identifying flexibility issues, which are not related to any particular "promise of convergence", but rather are answered based upon the whole work as such.

3.2.1.1. Properties of the systems

When looking at the processes of change taking place in infocom, one is struck by the speed of development in the Internet compared to television and telephony. Having defined the converging areas, which provide the different infocom phenomena observed, this project looks at differences between these areas.

The aim is to point out differences in the innovation rate in the areas of computer/networking and television, and to clarify the causes of these differences. This is done by identifying inherent properties of these areas, which might serve to

⁹⁵ For example the notion of “Technological Systems” as presented by Hughes.

explain drawbacks and advantages of the systems. The investigation goes beyond the notion of “analogue vs. digital” and looks at a number of important topics characterizing the different areas.

Flexibility can be identified in many aspects of a communication phenomenon. The focus here is mainly the devices or appliances of the users. Here, an important difference between the “new” computer/networking area and the “old” area of television is the computer/networking world’s strong separation or dichotomy between hardware and software. This is a property of computer/networking where explanations to its high rate of innovation are sought.

These considerations lead to the following research question:

- How does the separation between hardware and software influence the flexibility and rate of innovation of the computer/networking area?

3.2.1.2. Standards and standardisation issues

The areas where flexibility, compatibility and interoperability are important issues are usually subject to intensive standardisation. This means, that there are standards defining how images are displayed, how sound is generated, which forms the electric signals have, etc. The purpose of these standards is providing common definitions of the technical properties of the systems. However, an innovation or improvement often implies a change of standards. Incremental innovations will often involve minor adjustment⁹⁶ of existing standards, while radical innovations might imply the creation of a whole new standard or set of standards.

Therefore, the nature of standards in the various areas is expected to be of vital importance to the area’s ability to innovate and evolve. Assuming that the rate of innovation in a given area depends on the ease with which users can switch standards (or the flexibility of the standards themselves), the flexibility status in the various areas is examined. Here it is expected to find that the appliances and standardisation procedures used in the computer/networking area are considerably more flexible than that of the computer/networking area⁹⁷.

Apart from the standards themselves, the process of standardisation is crucial to the flexibility and innovation rate of a system. Therefore, the focus will also be on the organisations developing the standards of the computer/networking and television areas.

The following research question can be extracted from the above:

⁹⁶ As e.g. the switch from VGA resolution (640x480) to SVGA (800x600)

⁹⁷ We have e.g. NTSC vs PAL, and MP2 vs DivX;-)

- Do the standards and standardisation processes of the computer/networking area favour a higher degree of flexibility and a higher rate of innovation than those of the television area?

3.2.2. The Promise of Interoperability

Among other things, convergence is about being able to view the information or communication content typical to one system on the appliances of another. An obvious example is viewing a television broadcast on a computer. At present, many of the convergence phenomena, which can be observed, aim at interfacing various communication hard- and software.

The main problem that interfacing attempts to solve, is the differences between a number of standards of the various areas. As is shown in this project, these standards fall in three main categories: *Signal, Interconnection and Content Standards*. In order to map the landscape in which we operate, an overview of the crucial standards is given in the basic study in Chapter 7.

An important aspect in relation to this is the possibility of content migrating from one area to another as opposed to the “pure” convergence that implies a “fusion” of the various areas. One can imagine the maintenance of status quo with relatively clear borders between computer/networking, television and telephony. In such a scenario, convergence would be made possible by interfacing. An alternative scenario, however, is the adoption of one area’s standards in other areas – the most likely outcome probably being the use of computer/networking standards in other systems. This way, the interfacing problems might be overcome by a future migration towards the technologies, which today primarily are in use on computers⁹⁸.

The question of *convergence vs. migration* is indeed a very central one: will we in the foreseeable future see the borders between areas remain and convergence take place only in the form of interfacing, or we will see a cross-area migration towards the standards of one of the three areas? The outcome is not easily predictable, but pointers towards a likely development can be found via an analysis of the existing possibilities of migration and interfacing.

The research questions extracted from the above are:

- What are the problems and opportunities of using appliances of one area with the infocom content of other areas?
- Which are the interfacing obstacles of using appliances from different areas together?

⁹⁸ The use of Mpeg2 in terrestrial DVB is an example of this.

- How easily can information and communication migrate from one area to another?

3.2.3. The promise of Quality

Looking into selected infocom phenomena, the case studies shed light on these differences and properties of appliances and infrastructures. Special attention is given to the question of flexibility expressed as the ability to easily incorporate both incremental improvements (e.g. an increased picture resolution) and radical new phenomena (e.g. stereoscopic vision). The underlying assumption is that a high degree of flexibility will enable the appliances of a particular area (mainly computers and TV sets) to be used with new and improved forms of infocom.

This leads to the following two research questions:

- What are the differences between the computer/networking area and the television area in terms of incorporating radical innovations?
- What are the differences between the computer/networking area and the television area in terms of incorporating incremental innovations?

3.2.4. The Promise of Interactivity

Not only the consumer devices or appliances can be subject to convergence in the sense, that they are used for another form of infocom than originally intended. Also the infrastructures carrying the information – be it a cable-TV network, telephone wires or a WAN⁹⁹ can be involved in the convergence and carry another type of content than it was originally intended for.

Infrastructure can be defined narrowly in terms of copper or fibre cables, but also more broadly, including switches, routers, protocols, etc.

Definition 12: Infrastructure (a stipulative definition).

In relation to this, a number of questions arise. For example: Will download as known from the Internet be able to compete with broadcast as we know it from cable television? And will broadband Internet access make the distribution of traditional television obsolete. To answer these questions, one must look at the basic properties of not only the nature of the information and communication, but also the characteristics of the various infrastructures.

⁹⁹ Wide Area Network.

The main question for the future is whether we will see a coexistence of the infrastructures of the computer/networking and television areas, or we will see a migration onto one generic type of infrastructure¹⁰⁰ - or might we see the infrastructures of both areas adopt the capabilities of the other one?. To answer this question, one must look at the basic characteristics of the areas' infrastructures. As the infrastructures originally were developed for the specific purposes of the area in question, important differences between the infrastructures must be expected.

If one wanted to predict the future infrastructure, it would be necessary to compare the strengths and weaknesses of either infrastructure with the generic types of infocom, which can be imagined running on the various infrastructures. Therefore, this project aims at clarifying the coherence between the infrastructures of television, and computer/networking with the possible generic information and communication forms identified.

An alternative to the scenario of one unified network is the simultaneous use of two or more generically different networks. If different networks could be used in combination for a form of *hybrid communication* - utilizing the strengths of each network – this could be a viable alternative to a “unified” network, and could ensure a symbiotic co-existence of the TV, telephone and computer network.

The above considerations lead to the following research questions:

- What are the important differences in the ways in which information and communication are distributed?
- What are the options of hybrid forms of communication?

3.2.5. Summary of research questions

In total, the research questions of this Ph.D.-project are the following:

Broad research questions

- How does the separation between hardware and software influence the flexibility and rate of innovation of the computer/networking area?
- Do the standards and standardisation processes of the computer/networking area favour a higher degree of flexibility and a higher rate of innovation than those of the television area.

The Promise of Interoperability

¹⁰⁰ For example an abandoning of cable-TV-networks in favour of WANs.

- What are the problems and opportunities of using appliances of one area with the infocom content of other areas?
- Which are the interfacing obstacles of using appliances from different areas together?
- How easily can information and communication migrate from one area to another?

The Promise of Quality

- What are the differences between the computer/networking area and the television area in terms of incorporating radical innovations?
- What are the differences between the computer/networking area and the television area in terms of incorporating incremental innovations?

The Promise of Interactivity

- What are the important differences in the way information and communication are distributed?
- What are the options of hybrid forms of communication?

4. Research Design

This chapter explains how the study is undertaken. It explains the methodological choices and describes, how the research questions and empirical studies are put in relation to one another. A discussion of the relevancy of the chosen approach can be found in the “Outlook and Discussion” chapter.

4.1. Method

The studies of this Ph.D.-project are carried out with three main purposes. Firstly, the studies investigate the new phenomenon of convergence in an *exploratory* manner, identifying relevant areas of development. Secondly, the study is *descriptive*, as it aims at observing and reporting the developments taking place. Thirdly, the study attempts to explain the causalities of current and future development, thus also having an *explanatory* angle.

As the study investigates an ongoing phenomenon, the boundaries of which are not easily identifiable, the method used is *inductive*. The study contains no verification of predictions in the strict hypothetic-deductive sense. This leads to the use of a *qualitative* approach, focusing more on "how" and "why" type questions rather than "how many" and "how much".

The main empirical part consists of a *multiple case study*, where three cases are investigated, each of them relating to one of the three earlier identified "promises of convergence". The information gathering of the case studies is primarily based upon observation of *physical artefacts*, *documentation* and *articles*. To some extent, practical experiments and proof-of-concept prototyping has been carried out in order to either get hands-on experience in a particular field or to prove that a suggested concept is practically applicable.

A more elaborate description of the methodological considerations can be found in the “Method” chapter in the appendix.

4.2. Research Questions in Relation to Empirical Studies

The purpose of this section is to explain and describe the empirical information by which the conceptual questions and research questions of this project are analysed.

With the purpose of answering the posed conceptual questions and research questions, a number of studies are carried out. In the case of research questions, the related studies have the form of case studies, i.e. studies of actual phenomena that, when investigated, serve to answer the research questions. The conceptual questions are partly answered through theoretical discussion, partly through a conceptual study of

the basic characteristics of existing information and communication phenomena (the “Information and Communication Taxonomy” chapter).

Obviously, some of the studies undertaken have clear relation to particular conceptual questions or research questions. But it has not been an intention to make a rigid pairing of questions and studies. Thus, as explained in the following, the analysis of each question will draw upon a variety of studies. This means, that even though the conceptual study *mainly* is intended as shedding light upon conceptual questions (and similarly for the relation between case studies and research questions), the findings in each study are applied in the analysis of any question relevant.

Still, the conceptual questions serve to define and clarify the conceptual framework of this topic. Great care is applied in not creating self-explanatory models by erroneously incorporating the case study findings in the conceptual framework. The effect of this is, that overlap mostly goes in one direction – i.e. the use of the conceptual study in explanation of research questions and *not* the use of case study finding in the creation of the conceptual framework.

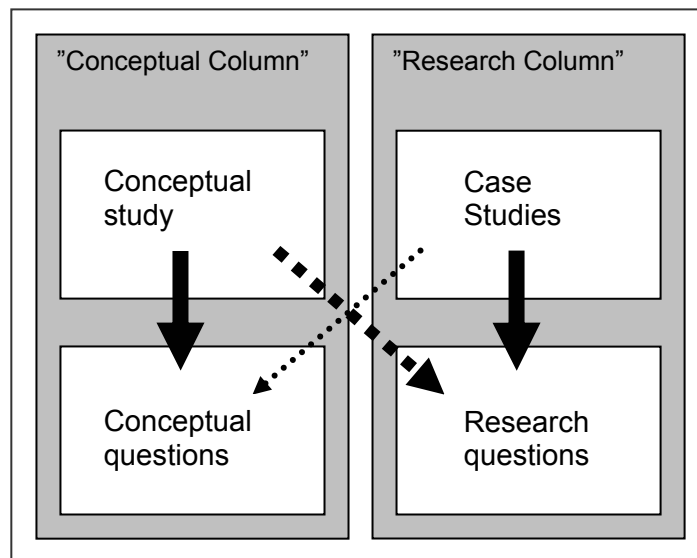


Figure 4: Relations between categories of conceptual questions, conceptual study, research questions and case studies.

4.2.1. Conceptual Questions and the Associated Study

The conceptual questions are rather fundamental in nature. They are concerned with the basic properties and conditions of converging areas, communication and information. Rather than pinpointing certain possible development paths, their purpose is to define a framework and clarify a number of basic characteristics. One could say

that the purpose is a *mapping* of the relevant aspects of information, communication, infrastructure and appliances. Hereby, a basis for the following and more specific research questions is provided.

The conceptual study, “Information and Communication Taxonomy” investigates the basic properties of the information and communication phenomena, which can be observed in the various converging areas, and offers a taxonomy of communication and information consumption. This study especially focuses on answering the conceptual questions under the “Information and Communication Characteristics” and the “Areas” headers.

The other conceptual question, relating to a proper framework of understanding of the converging areas, is primarily answered in the light of existing theoretic concepts in the area of economy of innovation (in the theory chapter under the “Economics of Innovation” header).

This discipline of conceptual consideration has a supporting role in relation to the Ph.D. project. It is not only necessary as foundations of the entire thesis, but also useful in their own right - and quite novel in the sense, that they examine areas, which have not yet been subject to a similar investigation.

4.2.2. Research Questions and Empirical Studies

The empirical part of the project mainly consists of a number of case studies¹⁰¹. These cases are chosen for their usefulness in relation to particular research questions. To cover the research questions, three main case studies have been selected. However, to provide an empirical basis of all three case studies, a fundamental study of the properties and standards of the television and computer/networking area is carried out. Further supplementing the knowledge of standard-setting organisations plus the background of the development of television, two supplementary studies can be found in the appendix.

4.2.2.1. The Basic Empirical Study

The “Signal, Interconnection and Content Standards” study looks at the actual standards making out the hard- and software of the television and computer/networking areas. It describes the important differences and similarities between the two converging areas, and identifies a number of key areas of interest in relation to interoperability, interactivity and quality. Furthermore, this study introduces to – and accentuates the relevance of - the three main case studies.

¹⁰¹ Each having their own associated proof-of-concept prototype.

The findings of this study feeds into all categories of research questions, but particularly those under the “Broad research questions” header. This group of research questions is, however, not limited to this particular study, but are answered on the basis of all empirical studies.

4.2.2.2. The Three Case Studies

The three major case studies are consequences of the three “promises of convergence” presented on page 3, where the three areas of *Interoperability*, *Interactivity* and *Quality* are described. Each among the three case studies is related to a particular “promise” (and hence to a set of research questions derived from this particular promise), as illustrated in the figure below. The only exception from the coupling of one promise to one case study is in the quality “promise”, where the incremental quality improvements are examined in the TVPC case, whereas the radical ones are examined in the modality case.

The actual case studies are described in later chapters. A short description of each study will however be given here:

- *The TVPC Case Study* – As one of the main promises of convergence is the use of appliances and infrastructures originally belonging in one area for a communication or information consumption purpose traditionally taking place in another area, the traditional household computer is investigated. The aim is to clarify the computer’s status of usability for this purpose and the availability of suitable hard- and software. It is also the aim to identify the potential of the computer in carrying novel types of infocom as well as delivering incremental quality improvements. This case especially focuses on answering the research questions relating to compatibility and interoperability.
- *The Modality Case Study* – Another important topic of convergence is the promise of increased quality. This promise can be seen exemplified by the introduction of the North American HDTV¹⁰² standard. However, the incremental increases in sound and picture quality are not the most relevant here – they are investigated in the TVPC case. This case describes the television and computer/networking areas’ ability to adopt and stimulate the development of radical innovations in the quality of infocom content. The central topic here is stereoscopy, i.e. the possibility of displaying images in three dimensions. Therefore, the flexibility and potential of computers and television sets in this particular respect are compared. This case especially focuses on answering the research questions relating to flexibility and quality.

¹⁰² HDTV: High Definition TeleVision.

Also questions having to do with compatibility and interoperability are illuminated by this case.

- *The Hybrid Communication and Information Case Study* – Also involving the characteristics and potential of the different network infrastructures, this case expands somewhat beyond the view on appliances. The Hybrid Communication case is inspired by considerations on technically appropriate use of the various available infrastructures¹⁰³, and investigates the potential of combining the use of networks into a form of hybrid communication and information consumption taking place on a computer. It sets off with the basic notion, that until the appropriate network structures¹⁰⁴ and organisation of the Internet is in place, other ways of gaining interactivity must be explored. This case especially focuses on answering the research questions relating to the promise of interactivity.

A graphical representation of the case studies and their relations to groups of research questions looks as follows. The circles indicate linkages between case studies and promises, but they do not exclude that answers to one promise's research question can be found in another case study than indicated here.

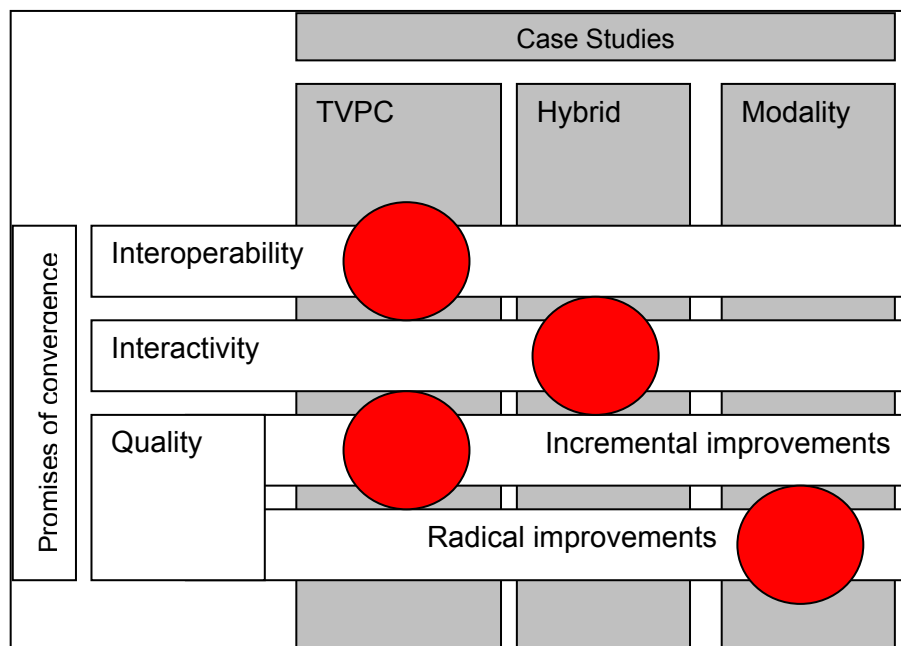


Figure 5: Relations between promises of convergence and case studies.

¹⁰³ These considerations deal with the question of *which* forms of infocom are suitable to run on *which* types of network.

¹⁰⁴ Especially the highly topical concept of *multicasting*.

4.2.2.3. Supporting studies

In addition to the studies mentioned above, two supporting studies have been carried out during the Ph.D. project. They are not used in relation to the research questions of this project, but serve as background information. Due to their primarily supporting roles, these studies are located in the appendix.

- “New Standardisation Fora and Their Relationships with Traditional Standardisation Organisations” investigates the organisations setting the standards in the various areas and gives an overview of the processes of standardisation with focus on important issues such as speed and flexibility.
- “The Shaping of Television” describes the history of television, explaining how it developed into a one-way, one-to-many communication system instead of a system more resembling telephony or Internet.

4.2.3. Summary: Relations between questions and empirics

There is not a strict separation between the conceptual study and case studies in the sense that overlaps are attempted avoided. Neither is any specific case study designed with the sole purpose of answering one particular research question.

However, a main tendency of *some* studies being suited for *some* questions remain. This is unavoidable, as no study can serve all questions equally well. An illustration of the main relations between questions and studies looks as follows:

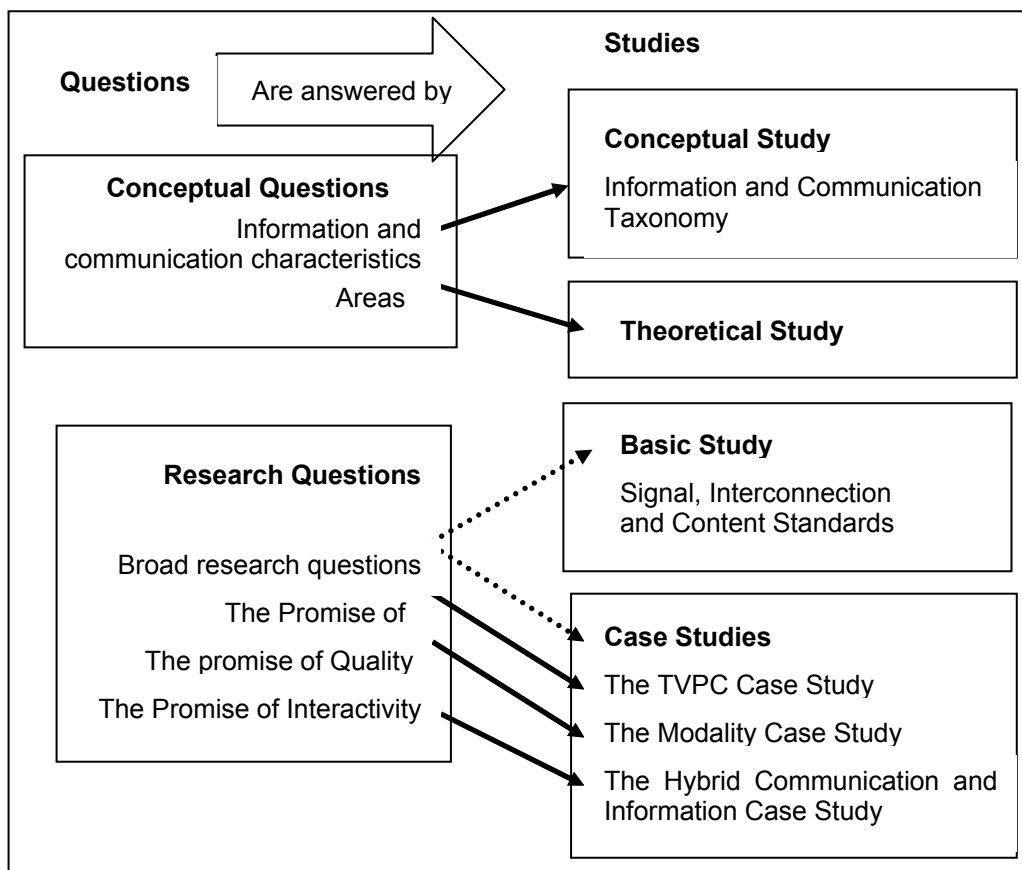


Figure 6: Main relations between groups of questions and studies.

This figure represents the further steps in this work. When coupled with the chosen theory, described in the chapter below, the studies and questions presented here lead to the findings and conclusions of this dissertation.

5. Theory

In this chapter, a number of theoretical concepts are introduced. The following is a presentation of a larger set of theoretical approaches among which some are selected for application on the further analysis of the cases and for answering the research questions. As such, the aim is partly to draw a picture of available relevant theories, partly to select a number among them and describe why these particular ones are useful and why some have not been used.

The following sections present theories drawing upon for major theoretical concepts. Firstly, explanations to the research questions are sought within the framework of *economics of standardisation*. Here, a number of models and theories exist, which are in accordance with the techno-centric focus of this report.

Secondly, a number of theories from the field of *economics of innovation* are presented. Here, the perspective is raised from considerations around markets and competing technologies. The focus is innovation at a larger scale. There is some overlap between the concepts and ideas of this theoretical field and those of the previously mentioned. For example the “competition of systems” could be said to belong in either field. Still, the separation is retained due to the differences in perspective – the focus in economics of standardisation is clearly more centred on technical issues than that of economics of innovation. This latter section is considerably smaller, as the main bulk of explanatory theories come from the economics of standardisation.

Two other theoretical and modelling frameworks are presented here: *information and communication theory* and *media theories*. The borders between these two areas are somewhat unclear. The aim of presenting models and theories within these fields is to be able to properly describe and analyse the concepts of *information consumption* and *communication*¹⁰⁵. As is shown, there is no clearly defined framework encompassing all relevant aspects of the convergence process, which is the reason for the considerable modelling work (in the “Information and Communication Taxonomy” chapter) in this thesis.

¹⁰⁵ *Infocom* is a constellation of the two terms information (or information consumption) and communication.

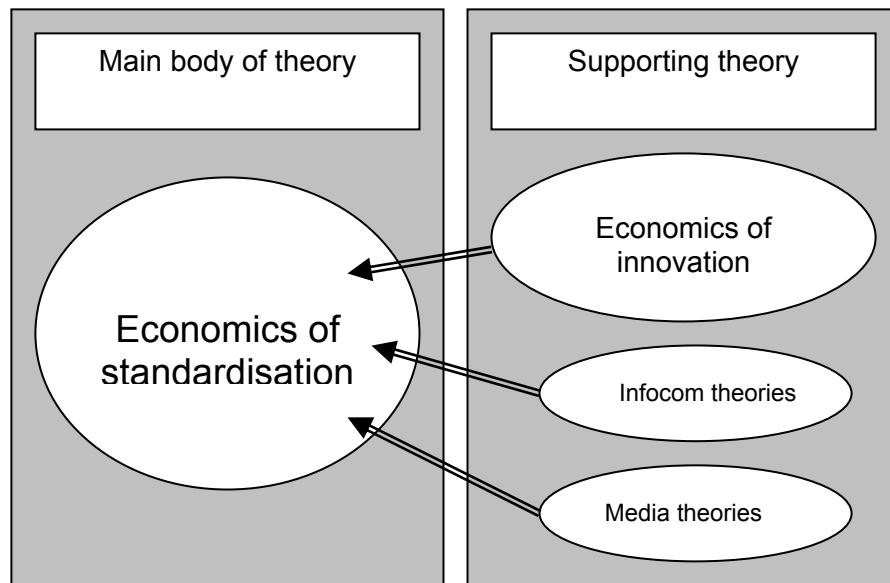


Figure 7: Elements of the theory and their relations.

Among of the bodies of theory, the economy concerning standardisation issues play the major part, whereas supporting theoretical approaches - among which the economics of innovation is the most important - complement the standardisation theory with the purpose of defining a complete and suitable body of theory covering the topic of this project.

This chapter aims at giving an introduction and some elaboration on the various relevant theoretical approaches. The following sections present the important theoretical concepts. Where possible, the paragraphs are sorted by concepts rather than the names of theories or theorists.

5.1. Economics of Standardisation

In the recently emerging research field of convergence, all sorts of perspectives can be – and are - applied. The perspective of this particular Ph.D.-project is on the technical standards involved in information consumption and communication in the converging areas. Thus, the bulk of the applied theory can be found within the field of *economics of standardisation*. This is a fairly recent theoretical tradition, which aims at explaining the processes of development and selection processes of markets, which are subject to direct and indirect externalities.

In this project, the definition of the term *standard* is much broader than for example the purpose of defining threads of nuts and bolts. Standards denote the systems and sub-systems at many levels in the convergence process. Standards apply to virtually all the phenomena that can be observed in the areas of television, telephony and computer/networking.

A standard can be defined as an agreement between some (but not necessarily all) players in a certain field where the topic of agreement is the technical specifications of various aspects of the communication technologies.

Definition 13: Standards (a stipulative definition for this work).

We often distinguish between *de jure* and *de facto* standards, depending upon how the standards emerge. The two arch-typical origins of standards are either the specifications of a standardisation authority, or a consortium of companies and other market actors. We also distinguish between sponsored and unsponsored *de facto* standards, where the sponsorship indicates, that the standard is backed by market actors – e.g. the aforementioned consortia. Accordingly, we define *de jure* standards according to their degree of legislative support.

| De Facto | De Jure |
|-------------|-----------|
| Sponsored | Mandatory |
| Unsponsored | Voluntary |

Figure 8: The standards matrix.

5.1.1. The relevance of a standards perspective

When investigating the convergence phenomenon, it is obvious that all areas of infocom are saturated with standards. Whatever form of communication or consumption of information is picked, there are standards governing its use. Standards specifying cable connections, screen aspect ratios, structure of electric signals etc. Standards thus act as building blocks of the networks of television, telephony as well as computer/networking.

It is important to stress the fact that a standard does not necessarily have to be developed or approved by any authority to actually be a standard. Many of the relevant standards in infocom are *de facto* standards, which have emerged because there was a need for a common agreement on a certain technical or organisational property.

The research problem and derived research questions are to a large extent analysed in the perspective of economics of standardisation. Due to the “standard-centric” approach of this project, a large proportion of this chapter consists of economics of standardisation. The convergence phenomenon is subject to analysis from perspectives

within the domain of standardisation economy - a theoretic tradition that has its strength in describing market behaviour in situations of standards competition.

The whole development of information and communication forms in TV, telephony and computer/networking can be viewed as systems of standards in succession, in competition and in cooperation. The standards help making systems work. They are the necessary building blocks, which – like a common language - enable communication between different individuals and components. Standards define the various systems and the adoption decisions of those interested in joining either competing system.

But standards do not only help to construct functioning information and communication systems. They can also – having established themselves and being widely adopted – stand in the way of further development. Either by being too rigid to incorporate new incremental innovations and improvements, or by resisting being replaced by radically different new standards, which more efficiently serve the same needs as the old ones.

In the following sections, relevant parts of the literature concerning the role of standards as determinants of technological change are presented. The concepts and theories here are applied to the cases of this Ph.D.-project, and form the main bulk of the theoretic rationale underlying the project.

5.1.2. Standards as goods

Among the many possible perspectives on standards, there is one particular important and fundamental in this body of theory. This is the concept of *standards as goods*.

In common economical terms, goods come in four types. They can be ordered in a 2 by 2 matrix based on two sets of properties:

- Excludability – i.e. whether it is possible to exclude certain groups or individuals from use of the good.
- Consumption Rivalry – i.e. whether one user's consumption of the good leaves less for the other users.

These properties result in four generic forms of goods, represented in the matrix as follows.

| | Rivalous consumption | Non-rivalous consumption |
|-------------------|----------------------------------|--|
| Excludability | Private goods (e.g. bread) | Public goods (e.g. cable television) |
| Non-excludability | Commons (e.g. fish in the ocean) | Collective goods (e.g. terrestrial television) |

Table 1: The four generic forms of goods.

Standards can assume the form of whatever goods mentioned in this matrix. A description of various types of standards and the classes of goods to which they belong is made by Charles Kindleberger¹⁰⁶. As introduction, Kindleberger classifies standards as *public goods*¹⁰⁷, which for the purpose of this report is interpreted as a wide term within which more narrow classifications of standards can be defined. To further accentuate the properties of standards, they are classified as *strong* forms of public goods in the sense that they have economics of scale – i.e. the more users a particular standard has, the higher is the benefit to each of its users.

Kindleberger lists a number of generic types of goods in which standards - depending on their originator – can be grouped. For the purpose of this analysis, this is going to unnecessary detail. The important aspect of “standards as goods” is the effect that the benefit of users of a particular standard increases the benefit of that standard – a property that has very important implications for the behaviour of markets characterised by compatibility standards, as is described in the following sections.

5.1.3. Feedback and Externalities

The special case concerning compatibility standards – that the more users, a particular standards gains, the greater the benefit to all users – is in conflict with traditional neoclassical economic theory. The market of compatibility standards exhibit and *externality* – i.e. a benefit (or drawback) to other users of the system brought about by the entry decision of a new user - which cannot be compensated by e.g. payments between the old and new participants. This constitutes a so called *market failure*.

The important implication of externalities is that *big gets bigger*. When a user decides which one among a number of mutually incompatible standards to choose, size adds to the attractiveness and plays a major role in the user’s choice – leading to a majority of the new users joining the largest standard.

¹⁰⁶ Kindleberger, 1983, p.377.

¹⁰⁷ It should be noted that the literature differs considerably with regards to the definitions of “public goods” and “collective goods”. Kindleberger actually uses the term “collective goods” in situations where excludability is actually *possible*. This is in contrast with the definition used in this dissertation.

Based upon this idea of externalities and increasing returns, a major theoretical concept in this project is *Positive Feedback* introduced by W. Brian Arthur¹⁰⁸, explaining how network markets are prone to tipping as a result of a slight market advantage of a particular standard at an early stage of the process of inter-standard competition. In short, positive feed back consists of two separate effects working in the same direction:

- Externalities – leading to a “big gets bigger” effect
- Increasing returns – leading to a “more is cheaper” effect.

Increasing returns can be observed in knowledge-based economy, where the cost of producing one extra unit is constantly falling with the number of total units produced. This is in sharp contrast to the traditional economy, where scarcity of resources leads to diminishing returns – for example, if raw material supply is running short, manufacturers will start looking for alternative materials. In knowledge based economy, the situation is the opposite: While the initial cost of developing a new product (for example a computer operating system) is very high, while the cost of producing one extra unit (for example a CD with the operating system) is very small.

The effect in economic terms is that instead of having a stable development with one predictable point of equilibrium, we have a scenario with multiple possible equilibria. When seen as competition between standards, Arthur illustrates the process of competition between compatibility standards over time as a walk on a convex surface.

¹⁰⁸ Arthur, 1990.

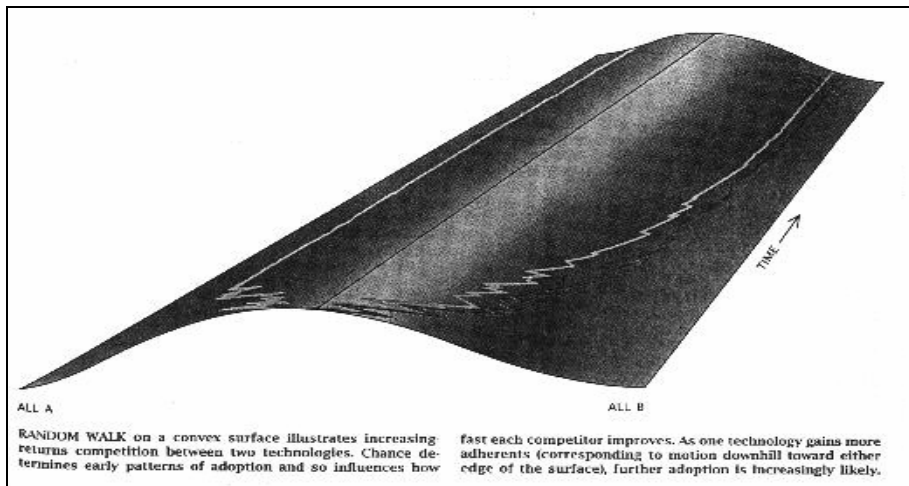


Figure 9: Competition between two compatibility standards illustrated by a convex surface¹⁰⁹

The consequence of positive feedback is that early occurrences in the life cycle of a compatibility standard have far-reaching implications. Once a sufficient lead has been achieved by any particular standard, the other standards will have difficulty displacing the leader. Even in situations where the rival standards are superior in technical terms or other aspects, it is difficult to compete with the sheer size of the leader.

The idea of a convex surface is useful in illustrating the “tipping” effect of compatibility standards markets. However, the surface only has room for two competitors (one at each side of the surface). As is the case with the seductive three intersecting sets, one should be careful, when being inspired by Arthur’s model of a convex surface, *not* to view any standards competition as necessarily taking by only *two* competitors. There might be much more than just two standards competing.

Author’s comment 2: The risk of the “convex surface” perspective.

Supplementary to the convex surface, Arthur compares the mathematical processes of standards competition to a game of probability, where balls are added to a table, one at a time. The balls can be of different colours, and the colour of the ball to be added next is unknown. However, the probability of a given colour depends on the current proportions of colours on the table¹¹⁰. Based on mathematical models, Arthur claims,

¹⁰⁹ Arthur, 1990, p. 81.

¹¹⁰ Arthur, 1990, p. 82

that the proportions of each colour must settle down to a “fixed point”. This fixed point must be one of the possible equilibriums of which Arthur speaks.

The feedback mechanism of this model is obvious, but in cases of compatibility decisions, effects are actually even stronger than Arthur describes. He fails to take into account that while the colour of a ball, once it’s on the table, remains the same; the choice of a user participating in a network of compatibility standards is subject to constant revision and thus *doesn’t necessarily remain the same*¹¹¹. Therefore, while the equilibrium in Arthur’s model often will result in one large and several small standards, the reality is, that the end result will be an equilibrium of one standard with the competing standards extinct.

The reason for pointing out this flaw is the focus of this project. With appliances such as television sets, telephones and computers being replaced every couple of years, buyers’ purchase decisions (and their thereof derived revision of standard affiliation) are quite frequent. This leads to a market which on one hand has strong feedback mechanisms as not only new users, but also those who made a regrettable compatibility decision have incentives to join the largest standard, but on the other hand, as replacements are frequent, it leaves opportunities for new entrants with alternative standards.

5.1.4. Tipping

With network effects and increasing returns in play, the balance of market share between competitors is prone to *tipping*, which is the *tendency of one system to pull away from it’s rivals in popularity once it has gained an initial edge*¹¹².

As the term indicates, tipping is a somewhat sudden process. It occurs when a particular system has achieved a sufficient *critical mass* of users, economies of scale and related products and services – making the many reasons for choosing (or switching to) this particular system so obvious, that they apply to a larger number of users.

This could for example be observed in the case of home video systems VHS and Betamax, when, during the 1980’s, the number of pre-recorded VHS video cassettes available, the variety of VHS machines and the number of friends and relatives using VHS became sufficiently overwhelming evidence to the consumers, that Betamax wasn’t a viable option to buyers¹¹³.

¹¹¹ Most Amiga users, for example, at some time realized the necessity of switching to an alternative platform.

¹¹² Katz & Shapiro, 1994, p.106.

¹¹³ Oest & Edwards, 1996.

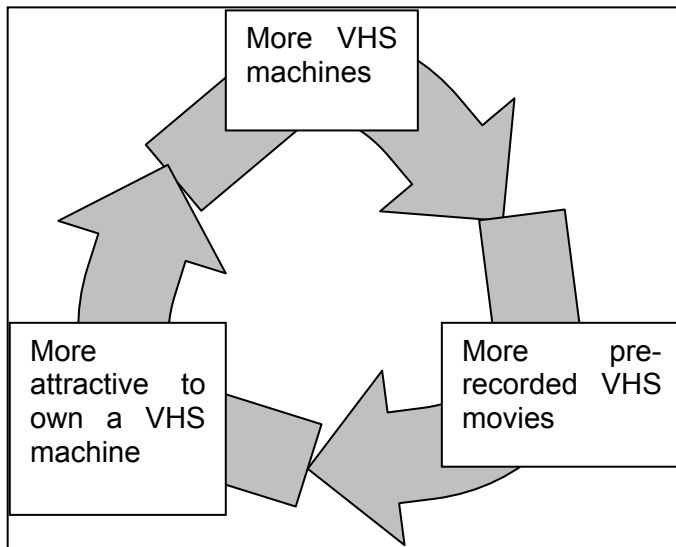


Figure 10: Example of mechanisms resulting in tipping.

A further reinforcing effect can be observed: Once a particular system or standard gains momentum, manufacturers of so called “complementary assets” mentioned on page 78 have further incentive of adding to the variety of services and products related to the winning system – thus further adding to its attractiveness.

5.1.5. Path Dependence and Lock-in

Also based on the concept of increasing returns, W. Brian Arthur introduces the concept of *Path Dependence*, which describes the behaviour of markets in selecting often inferior technologies. The idea behind this term is that the market selection among incompatible standards often leads to sub-optimal outcomes. These outcomes can be regrettable in the sense, that if decision makers (be it governments, companies or private users) had known from the start, that another choice would have lead to greater utility, they would have selected that particular standard instead¹¹⁴. Now, due to imperfect information, they did not know at the time of selection, which choice would turn out to be the best.

Due to these circumstances, the economies risk being locked into inferior paths of development¹¹⁵, resulting in a situation where users are stuck with a choice, which is not the optimal one (or at least not the *uniquely* optimal one) - and where a switch to the optimal solution is impossible or costly.

¹¹⁴ The classic example of this is the market’s choice of the supposedly inferior VHS video recorder format instead of Betamax.

¹¹⁵ Arthur, 1990, p. 84.

These considerations are relevant in relation to this Ph.D.-project, as they aim at explaining how the market can get stuck in the continued use of a seemingly unsolvable inappropriate technology choice. Many cases – especially those having to do with a radical transition to a new and improved system – can benefit from being analysed in the light of path-dependence.

This concept has been taken further by Liebowitz and Margolis¹¹⁶, who present three degrees of path dependence, differing in two respects, namely whether the outcome of the selection process was *regrettable* or not (i.e. whether a better alternative could have been selected, and whether the situation can be – or at some point in time could have been - *remedied* (i.e. whether there is or was an opportunity of switching to a better alternative).

In every type of path-dependence, it is assumed, that information was imperfect at the original point of selection – i.e. that those who made the choices could not have predicted the outcomes of the various alternatives between which they could choose.

First degree path dependence occurs when a selection is done based on imperfect information that can not easily be remedied, but where the outcome happens not to be less desirable than the alternatives.

Second degree path dependence occurs when a selection is done based on imperfect information leads to a less than optimal outcome, but the outcome is costly to change (meaning in practical terms that it can not be remedied).

Third degree path dependence occurs when a selection leads to a less than optimal outcome, but where the choice can be – or at some point in time could have been – changed to the optimal.

Especially in the case of third degree path dependence, the work by Liebowitz and Margolis contains a criticism of the earlier works by Paul A. David and W. Brian Arthur, mainly on the topic of decision makers' means of predicting optimal choices of standards and remedying suboptimal choices. Their paper claims that the two arch typical examples of 3rd degree path dependence, namely the victory of the VHS video cassette format over rival Betamax and the adoption of the QWERTY keyboard layout aren't actually examples of 3rd degree path dependence.

¹¹⁶ Liebowitz & Margolis, 1995.

The three different forms of path dependence can be illustrated as follows:

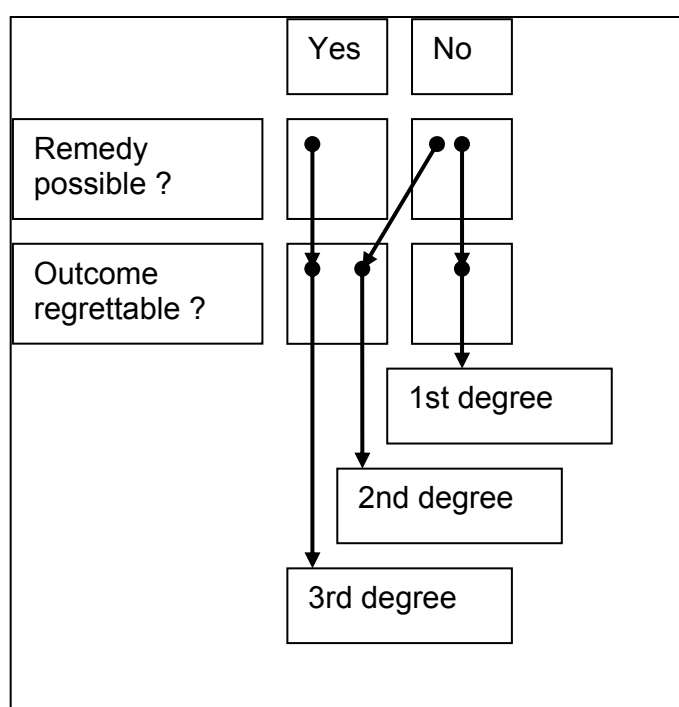


Figure 11: Liebowitz and Margolis' three degrees of path dependence (own graphical interpretation of reference's text).

One could argue that the figure does not wholly encompass the aspects of the three degrees of path dependence, as there is no distinction between a) the situation where the regrettable original decision was made on the basis of perfect information (i.e. remedy was possible from the very beginning) and b) the situation where information was imperfect but where remedy becomes possible at some point in time¹¹⁷.

The “fourth” situation not drawn in the figure is the somewhat trivial one where there is a chance of “remedy” but no need for it, as the decision turned out to be optimal. One might say, that the two situations (1st and 2nd degree path dependence) are likewise trivial. And certainly, the case of 3rd degree path dependence is the most

¹¹⁷ Actually, there is no reason to make a sharp distinction between these two situations. When looking at the “opportunity” of remedy, this is nothing more than an opportunity to do the selection once more, only this time with perfect knowledge, (i.e. the knowledge that the standard originally chosen is less than optimal). One could also say, that perfect information is a necessary precondition for remedy – otherwise decision makers would not know what was the optimal solution.

interesting, as one can wonder *why*, when remedy is actually possible, it is not applied. Why do users stay with the suboptimal choice, when it actually pays off to switch?

Liebowitz and Margolis quotes a number of theorists on this issue, and the general tendency is explaining the reluctance to remedy with a): *coordination failure* – users would like to switch, but are unable to properly coordinate the transition, so the suboptimal standard is retained and b): Owners of e.g. literal communication networks or patents blocking the transition.

Path-dependence is particularly relevant, because the converging areas might display different degrees of path-dependence – which would serve as an explanation of why development takes place at a faster rate in some areas than in others.

5.1.6. Installed Base

On network markets, a wide adoption of one's standard is desirable. The most obvious reason for this is, of course, that many users means many products or services sold. This effect, however, applies to all market forms. As indicated earlier, on markets with compatibility standards, other benefits are related to having a wide adoption, namely the fact that it makes the standard in question even more attractive to potential customers. In standardisation theory, this number of adopted units (which largely corresponds to the number of users) is referred to as the *installed base*. This concept was introduced by Farrell & Saloner¹¹⁸. It is strongly connected to the positive feedback considerations with its focus on the importance of already made purchases of equipment.

Companies and organisations operating on network markets have a strong focus of obtaining a large installed base, and many business considerations focus on quickly achieving a sufficiently large installed base, and then “let the positive feedback do the rest”. Here, one could say that the installed bases act as the *weight in the scales* that result in the *tipping* mentioned earlier.

In relation to this project, it is important to investigate the nature of the installed base. Especially when considering the computer as a system of hard- and software, one can wonder if an installed base (e.g. of Wintel¹¹⁹ computers) is indeed so well founded as the term suggests. When having to do with systems displaying the flexibility of computers, one must bear in mind, that software changes (e.g. to Linux), can alter the weight balance of installed bases much easier than in the archetypical case of video recorder formats, where the installed bases of machines as well as tapes were of a

¹¹⁸ Farrell & Saloner, 1986.

¹¹⁹ Wintel is short for Windows and Intel, the leaders in operating systems respectively CPU's at today's computer market.

much more tangible and less easily replaceable form than computers with their interchangeable hardware parts and easily changeable software.

5.1.7. Systems Competition

Network markets are not all alike. Various mechanisms apply to different degrees at different markets. One of the important distinctions between different forms of network markets is made by Katz and Shapiro¹²⁰, who describe the standardisation processes with focus on the distinction between *communication networks* and *hardware/software systems* - an angle the project explores in relation to the analysis on the hardware/apparatus level. The distinction done by Katz & Shapiro between communication networks and hardware/software systems is very fundamental with respect to the term *infocom* used in this thesis, as it touches upon some of the basic characteristics of information and communication¹²¹.

5.1.8. Hardware-software Systems and Communication Networks

In markets where compatibility is an issue, two important aspects of the products and services can usually be observed. These aspects are often presented as two (not necessarily mutually exclusive) generic types of systems, namely *Communication Networks* and *Hardware/Software systems*. Originally presented by Katz and Shapiro¹²², the distinction draws upon work concerning *one-way and two-way networks* by Economides and White¹²³

The distinction between communication networks and hardware-software systems resembles the distinction made by Kindleberger¹²⁴ between those standards designed to reduce transaction costs and those in which there are physical economies external to the firm. In the following, the notion of Katz and Shapiro is used, as the argumentation of these authors for the term are closer related to the topic of this project than that of Kindleberger.

Two communication networks are incompatible if subscribers on one network cannot communicate with those on the other network. Two hardware/software systems are incompatible if the components of one system do not work with components of the other system.

¹²⁰ Katz & Shapiro, 1994, pp. 93-115.

¹²¹ Hardware/software systems and communication networks are two different market forms – having to do with the content delivered: whether it is one-way or two-way communication – a distinction that is elaborated further upon in the “Information and Communication Taxonomy” chapter. **Error! Reference source not found.**

¹²² Katz & Shapiro, 1994, p. 94.

¹²³ Economides & White, 1994.

¹²⁴ Kindleberger, 1983, p.378.

Definition 14: Compatibility in communication networks and hardware/software systems¹²⁵ (a lexical definition).

The perspectives relating to the distinction between communication networks and hardware/software systems is a particularly relevant body of theory when examining the converging areas. The reason is that this project goes deep into the information and communication phenomena and analyses their fundamental properties. Here, it is highly important to know what the actual use of a system (e.g. a computer or a television set) is.

These properties of phenomena are analysed in the framework presented in the “Information and Communication Taxonomy” chapter, where the fundamental characteristics of phenomena are described.

5.1.8.1. Communication Networks

Communication is one of the two elements making up the central term of *infocom*. It is classical to the telephony area, where two individuals communicate in real-time.

Communication is a process by which information is exchanged between individuals through a common system of symbols, signs, or behaviour.

Definition 15: Communication (a lexical definition)¹²⁶.

A communication network is – as indicated by the name – a network in which a number of involved parties (often individuals) communicate. A classical example is a telephone network. This situation has interesting properties of positive feedback. This is due to the fact that the decision of an additional user to join the network has important social benefits to those already participating in the network. As mentioned earlier, this leads to concentration around networks that are already big, often locking in the markets.

¹²⁵ Quote from Katz & Shapiro, 1994, pp. 105). The authors add in a footnote, that... “Incompatibility can be one-way or two-way. Two-way incompatibility exists when components from one system simply don’t work in the other. One-way compatibility happens when a component from one system works in the other, but the reverse is not true...”.

¹²⁶ Merriam-Webster OnLine.

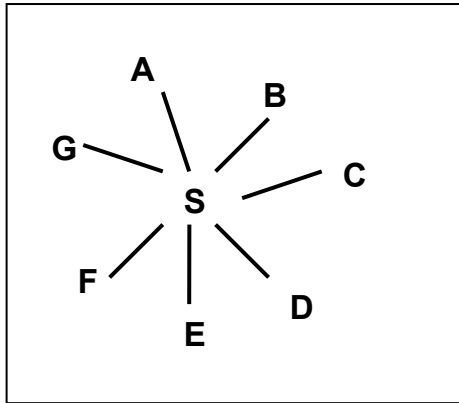


Figure 12: A communication (or two way) network. A-G are customers, S is a central switch¹²⁷

The communication network as defined by Katz and Shapiro is equivalent to the two way network defined by Economides and White. The latter mention a number of important observations on two way or communication networks:

*First, all components (AS, BS, etc.) are **complementary** to each other. Therefore any two of them can be connected to make a demanded **composite good** (such as ASB).*

*Second, components AS, BS, etc., are complementary to each other despite the fact that in industrial specification terms they are very **similar** goods.*

*Third, there is **reciprocity** or **reversibility**. Both ASB and BSA are feasible but different (though technologically very similar) because the spokes AS, BS, etc., can be travelled in both directions.*

*Fourth, **customers** tend to be **identified** with a particular **component**.*

*Fifth, composite goods that share one component, such as ASB and ASC, are **not necessarily close substitutes**.*

*Sixth, there are **network externalities**: the addition of a new spoke to an n-spoke network creates 2n new potential goods. The externality takes the form of the creation of new goods for each old customer. We could call it an economy of scope in consumption. Note that the externality affects directly the utility function of each consumer. There may be other secondary (indirect) effects through the markets (such as price changes), but this is not necessary or essential.*

*Seventh, we have assumed in the definition of the network that its components are **compatible**, so that their **combination** is of **value**. Compatibility may be automatic for certain goods (for example, sugar always dissolves in coffee), but for high technology products it has to be achieved by explicit or implicit agreement on certain **technical standards**.*¹²⁸

In the text quoted above, a very interesting term, *composite goods*, formed by the combination of *complementary components*, can be identified. This is particularly interesting, as it stresses the fact that components are of no or little use by themselves, but mainly are relevant in combination.

Due to the existence of adoption externalities and the positive-feedback mechanism in communication networks, customer's choices of which network to choose (if, indeed,

¹²⁷ Economides & White, 1994, p.2.

¹²⁸ Economides & White, 1994, p.1f (Bold types added by this author).

there are any alternatives to choose from), are highly dependent on the expectations concerning the *future size* of the network.

5.1.8.2. Hardware/Software Systems

A system different from the communication networks can be found, when consumers must purchase two different component which work in combination in order to derive any benefit from the products. A classical example is computer hard- and software: a computer is useless without software and vice versa.

In parallel to the earlier described communication networks, the central observations here are:

*First, in such networks, a **combination of any two components** does **not** create a demanded composite good.*

*Second, a one-way network **lacks reciprocity**.*

*Third, **customers** are often **not** immediately **identified** with particular **components** or **nodes**.*

*Fourth, typically in one-way networks, a **composite good** is a **closer** substitute with a good with which it **shares a component** than with goods with which it doesn't.*

*Fifth, such networks exhibit a **variant of consumption economies of scope**.¹²⁹*

The hardware/software or one-way network system is clearly more targeted towards consumption of *information* (as e.g. viewing of television) rather than *communication* in its strict sense. Hence, a stipulative definition of information is as follows:

Information consumption is one-way form communication, without the actual exchange of information between individuals characteristic of a typical communication process.

Definition 16: Information consumption (a stipulative definition).

As in the case of communication networks, hardware/software systems are subject to network effects (leading to the positive feed-back and lock-in mechanisms described earlier). However, these effects are of a different nature. Katz and Shapiro claim that adoption externalities in hardware/software systems are results of one buyer's adoption decision, which indirectly influences the future variety and price of components.¹³⁰ The reason for this is that many consumers joining a certain network will lead to greater economies of scale in development and production of both hard-

¹²⁹ IBID, pp.3-4 (Some passages left out – and bold types added by this author).

¹³⁰ Katz. & Shapiro, 1994, pp. 97-98.

and software – in turn leading to greater variety and lower price of components belonging to the system in question.

There is no reason to protest against the existence of this mechanism. But another mechanism not identified by Katz and Shapiro¹³¹ is also in play here: With the increasing complexity of hardware and software, especially in the computer¹³² area the question of support becomes relevant. Here, the availability of experienced people (friends colleagues and family), who can aid a novice user in setting up and using the system become important. Thus, other – more direct - externalities than those simply relating to the price and availability of hard- and software emerge¹³³.

Communication networks and hardware/software systems are often presented in a way that gives the impression, that a particular system either belongs to one system or the other. This is, however not necessarily the case. Often, a system will display properties of both categories.

5.1.8.3. Properties of the converging areas of communication networks or hardware/software systems

Among the three converging areas, it is quite straightforward to attribute properties of communication networks or hardware/software systems to the “older” ones. Telephony is a classical example of a communication network (or two-way network), whereas television, only sending information one way clearly is a hardware/software system with the television sets as hardware and broadcasts or video tapes as software.

In the case of computer/networking, the affiliation is less clear. Starting out as isolated computers with software installed, they clearly originated as hardware/software systems. But with the addition of networking capabilities, most prominently demonstrated by the Internet, computers to a still greater degree assume properties of communication networks.

¹³¹ Katz and Shapiro claim, that “In a hardware/software market, one consumer’s adoption decision (to buy the system or not) has *no impact* on other consumers given the prices and varieties of software available” (Katz. & Shapiro, 1994, p. 97)

¹³² Note, that the topic here is computers, not computer/networking. This means that even though computers today to a large extent serve as devices for communication, they can also exist as pure systems of hard- and software without modems and internet connections.

¹³³ It is an unsubstantiated claim by this author that it is important for a computer novice to seek advice among friends and family. However, the claim could easily be verified (or perhaps falsified) by a simple survey.

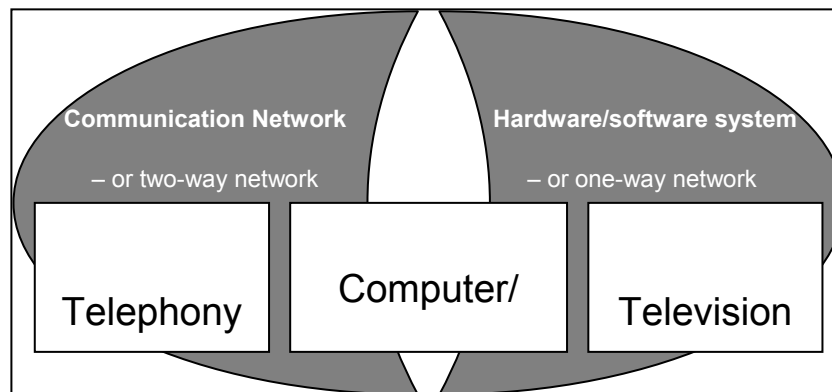


Figure 13: The three areas of Telephony, Computer/networking and Television in categories of Communication Networks and Hardware/Software Systems.

The establishment of the early telephone companies took place over a hundred years ago, and though competition is still fierce, the initial battles between systems are long past. Similarly, the area of television has been subject to little change over the years. At the Internet, the situation is quite different, with a number of various mutually incompatible forms of communication completing in these early stages of the Internet. This is particularly interesting, as it creates a situation where we have two older systems who have the opportunity of assuming new forms (by re-defining themselves) in combination (or competition) with a newer system, which is in the process of finding it's own form.

5.1.9. Complementary Assets

The phenomena, which can be observed in the process of convergence, are of a complex nature. They are not merely products that function by themselves (as e.g. a book or a hat), but systems composed of a number of components. A television set, for example would be of little use without broadcasts and a computer would be useless without software (as would indeed any hardware of a hardware-software system).

This illustrates the *systemic* property of the phenomena. And it has profound influence upon the ways, in which the development of information and communication services takes place. For a service or product to succeed, it must not only be good and useful by itself; often an array of complementary products and services must be in place in order for the phenomenon to succeed.

The notion of *systems* or (*technological* systems) is important when looking at the three converging areas. In the body of theory related to the economics of innovation, there is much discussion of how to define a system, and what the important properties of systems indeed are. This subject is treated further in the “Systems and Sectors” section of this chapter.

The array of complementary products and services supporting the core product or service accentuate the relevance of the notion of systems. The importance of these so called *complementary assets* is described by among others David Teece¹³⁴, who lists three generic categories:

- *Generic assets - no dependence exists between the basic service/products and the complementary asset*
- *Co-specialised assets - a both-ways dependence exists between the basic service/products and the complementary asset (e.g. VCRs and videotapes)*
- *Specialised assets which further can be divided into two categories:*
 - *Those, which depend unilaterally upon the basic service/products - e.g. VCRs in relation to TV sets (a VCR is useless without a TV).*
 - *Those, upon which the basic service/products unilaterally depend - e.g. TV sets in relation to VCRs¹³⁵.*

The importance of complementary assets is obvious in the case of hardware/software systems, where the core product is the hardware, and the software assumes the role of more or less specialized complementary assets. But also in the case of communication networks, complementary assets as e.g. communication infrastructures are crucial to the success of a product or service.

5.1.10. Strategic issues in standardisation

A very important group of players in the convergence area are the suppliers of the services, hardware and software that constitute the more tangible elements of the converging areas. Through their strategic decisions and actions, these companies greatly influence the development of electronic forms of information and communication. To fully understand the important processes and influences in the process of convergence, the incentives and possible actions of suppliers on the market must be taken into account.

An area where the efforts of companies are particularly visible is the field of standardisation. It can often be observed – and this is certainly also the case on the Internet at present – that the main issue characterizing the products and services introduced and promoted on the market is the association of services and products to particular standards.

Two of the main contributors of theory in this area are Stanley Besen and Joseph Farrell, who describe the landscape of decision of companies in markets characterised

¹³⁴ Teece, 1987.

¹³⁵ Oest, 1999.

by compatibility issues. In an 1994 article¹³⁶, they explore the strategic considerations and possible actions of the companies operating on what is known as *network markets*. The article primarily deals with the strategy towards horizontal competitors (as opposed to the vertical strategies concerning relations with suppliers¹³⁷).

The overall, fundamental strategic choice facing companies in network markets is the choice of whether to opt for *compatibility or incompatibility*¹³⁸. This choice is largely determined by the company's perception of its own strength. A choice of compatibility will lead to a so-called intra standard competition – and correspondingly, a choice of incompatibility results in an inter standards competition. The choice of compatibility will often depend upon the acceptance of owners of the standard, with which compliance is sought.

Building on the concept of positive feed-back and the proneness to tipping of network markets, the article stresses the importance of *expectations about the ultimate network size*¹³⁹ - it is not the current size that matters. Therefore, companies will try to manipulate buyers into believing, that their product or service will eventually win. Correspondingly, the actual technical quality is less important than the *perceived* technical quality. These findings of the importance of perceived customer benefit rather than actual customer benefit emphasizes the importance of marketing (rather than mere technical quality), favourising large organisations and companies with well-established marketing departments.

One additional tactical issue coming into play on a hardware/software market, not mentioned by Besen and Farrell, but pointed out by Katz and Shapiro¹⁴⁰, and also having to do with customers' expectations, is the fact, that firms will place great emphasis in influencing buyer decisions and locking in customers. A firm will have an incentive to lower the prices of hardware in order to create a larger installed basis and then profit from software sales - provided, of course, that the company in question sells hardware as well as software (or is in an alliance with a provider of complementary products and services).

Due to the market's tipping effect, the outcome of a standards battle often is *one big winner* and *many big losers*. The great prize leads to fierce competition, resulting in substantial losses among competitors¹⁴¹. Hence, a thorough evaluation on one's own chances to prevail in a standards battle is of crucial importance, and companies might therefore be inclined to agree upon a common standard rather than fighting it out. In

¹³⁶ Besen & Farrell, 1994, pp 117-131.

¹³⁷ These suppliers would often be those supplying the *complementary assets* mentioned elsewhere.

¹³⁸ Besen & Farrell, 1994, p117

¹³⁹ IBID, p.118

¹⁴⁰ Katz & Shapiro, 1994, p.99.

¹⁴¹ Besen & Farrell, 1994, p.119

cases where suppliers choose inter-standard competition, this might slow down market development, because buyers wait and see, which standard looks to be a winner.

When a common standard is agreed upon, the competition shifts from taking place between technologies, towards more traditional (in an economic sense) issues such as price, service and features¹⁴². This shift resembles the transition from the pre-paradigmatic phase to the paradigmatic phase described by Teece¹⁴³.

The strategic considerations in the Besen and Farrell article result in a categorization of three generic forms of competition, depending on the choices of the involved companies:

- Tweedledum & Tweedledee: Inter-standard competition, as both firms choose to compete.
- Battle of the sexes: Compatibility is preferred by the sponsors¹⁴⁴ of both technologies, but each firm would prefer it's own technology to become the standard agreed upon.
- Pesky little brother: One standard is dominating and wishes to keep its technology to itself, while less powerful competitors wish to produce in accordance with it.

These examples involve two firms, which is perhaps not very realistic, but makes the description of scenarios more simple than if all possible constellations should have been taken into account. When more than two firms are involved, competition will be composed of elements of the three generic forms.

Based upon the descriptions in the article, the three generic situations can be ordered in a table as shown below. Here, the typical tactics of firms in each of the situations are shown. Examples of actually observed tactics are shown in italics.

¹⁴² IBID, p.120

¹⁴³ Teece, 1987. p. 190

¹⁴⁴ The sponsor is the "owner" of a standard – typically the company holding crucial know-how or intellectual property rights.

| | Tweedledum and Tweedledee | Battle of the Sexes | Pesky Little Brother |
|---------------------------------|---|---|--|
| Typical scenario | Two competing sponsors with each their own interoperability paradigm | Two or more sponsors competing within the same interoperability paradigm | One established sponsor with large installed base - several small sponsors seeking interoperability |
| Market and technology positions | Symmetric | Symmetric | Asymmetric |
| Interoperability choice | Interoperability wanted by none of the sponsors | Interoperability wanted by all/both sponsors | Some sponsors want interoperability, other(s) don't |
| Tactics - with examples | Building on an early lead - <i>Windows and OS2 claiming wide adoption</i> Penetration pricing/Giveaways - <i>Internet Explorer vs. Netscape Navigator</i> Complementary assets - <i>Matsushita and Sony investment in movie companies</i> Product preannouncements - <i>Windows 98, new CPUs, USB, Bluetooth</i> Price commitment - <i>Promise by record companies that CDs would soon drop to a price far below vinyl records</i> | "Selfish" tactics | Intellectual Property Rights Copyright - <i>Intel Pentium, Apple operating system</i> Patents/software copyrights - <i>Intel Slot One CPU</i> |
| | | Making your own technology the standard | |
| | | Low cost licensing - <i>Intel with AMD, VHS vs. Betamax</i> Hybrid standard - <i>UNIX products</i> Commitment to joint future development - <i>VHS vs. Betamax</i> Future development of standard to third party - <i>UNIX</i> Promise of timely information about changes in standard | Frequent changes in technology - <i>Pentium II, Celeron, Sockets/slots</i> |
| | | Tactics to achieve cooperation | |

Table 2: The three generic scenarios in compatibility standards markets and the related tactics.

5.1.10.1. Open vs. Proprietary Standards

A central property – which to a large extent is a result of a strategic decision - of a standard is its *openness*, i.e. the extent to which its sponsor¹⁴⁵ allows others to use the standard.

¹⁴⁵ Typically the company that owns the intellectual property rights or specialized know-how related to the standard. This owner or sponsor can hereby block competitor's use of the standard and allow partnering companies to use it.

An open system:

”System and software environments based on standards which are vendor independent and commonly available.”

The UNIX X/Open consortium

Definition 17: An open system¹⁴⁶ (a lexical definition).

A particular standard is *neither* completely open *nor* closed (or proprietary), but rather something in between. The openness of a standard is determined by a number of factors, all relating to the strength of the standard’s sponsor, upon which the sponsor bases his choice of openness. These factors are¹⁴⁷:

- Control of the existing installed base
- Technical superiority
- Intellectual property rights

The sponsor’s decision of level of openness is guided by his expectations of the different rewards that result from the different possible strategic choices of openness. The expected reward is determined by the following formula:

Your reward = Total value added to industry X your share of industry value¹⁴⁸

The basic mechanisms behind this formula are that openness helps build a large system, while the sponsor’s share is smaller, because he must share the reward with the others using the same standard. Control (or “closedness”) typically hampers the development of a system, but in return leaves a larger share for the standard’s sponsor. In a world of extremes, this equals to a choice between “all of nothing” (control) or “none of everything” (openness). Fortunately, it is not impossible to – even with a closed standard – to obtain a large “total value added to industry” or, with an open standard, to obtain a reasonable “share of industry value”. Furthermore, in most cases the choice of openness will be something in the interval between the two extremes¹⁴⁹.

For each particular standard, it would be possible – if one knew all parameters influencing the share of industry value, to represent this share as a function of the openness. Correspondingly, it would be possible to represent the total value added to

¹⁴⁶ Shapiro & Varian, p.200.

¹⁴⁷ Shapiro & Varian, p.202. These aspects are also described under the notion of “Appropriability Regimes” by David J. Teece.

¹⁴⁸ Shapiro & Varian, p.198.

¹⁴⁹ The most desirable solution would be to have a standard, which can be open in the beginning, and thereafter closed when it has gained momentum, giving the owner of the standard a *big* share of a *big* market.

industry as a function of openness: The more open a standard is, the greater it contributes to the industry's value. In the latter case, however, it is important to consider the dominance of the sponsor. A dominant sponsor will have less need for the positive feedback effects and hereby induced growth coming from openness, and will therefore have a good chance of getting a widespread standard regardless of openness¹⁵⁰ – which obviously would make this sponsor inclined to a proprietary strategy¹⁵¹. The opposite situation would be the case for an upstart, who would typically aim at openness in order to establish alliances and neutralize the installed bases of competitors¹⁵².

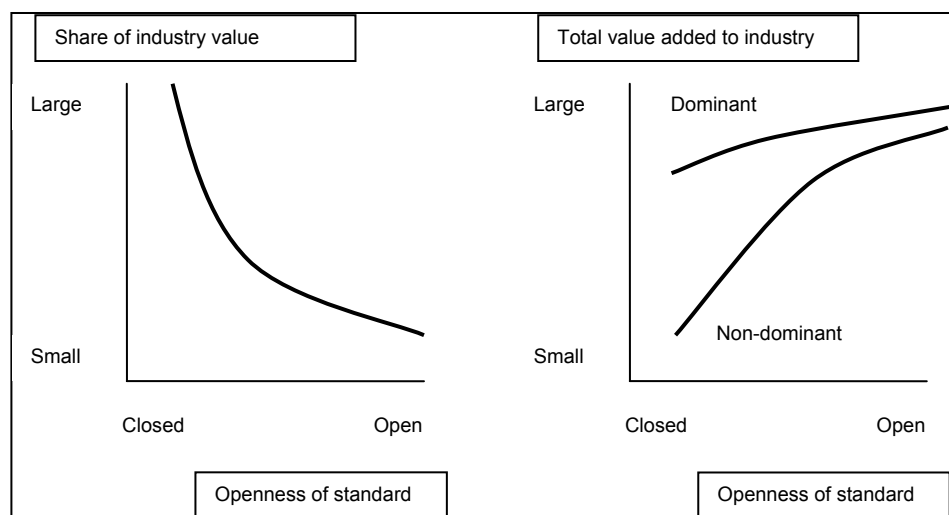


Figure 14: Value shares and total values as functions of openness. (own graphical interpretation of Shapiro & Varian's text).

When combining the two dimensions on the y-axis, one gets a graphic expression for the reward yielded by a given openness policy¹⁵³.

¹⁵⁰ Hence the flatter curve in Figure 14: Value shares and total values as functions of openness. (own graphical interpretation of Shapiro & Varian's text).

¹⁵¹ Shapiro & Varian, p.199.

¹⁵² Shapiro & Varian, p.201.

¹⁵³ When looking at these graphs, one should be aware, that there are no functions specified determining the shapes of the graphs. The shapes of the graphs are mere examples, and due to the vast number of variables involved (the degree of feed-back on the market, the technical quality of the particular standard, the "marketing muscle" of sponsors, etc.), it will be very difficult actually developing a mathematical function for the total value, the share of it and the reward.

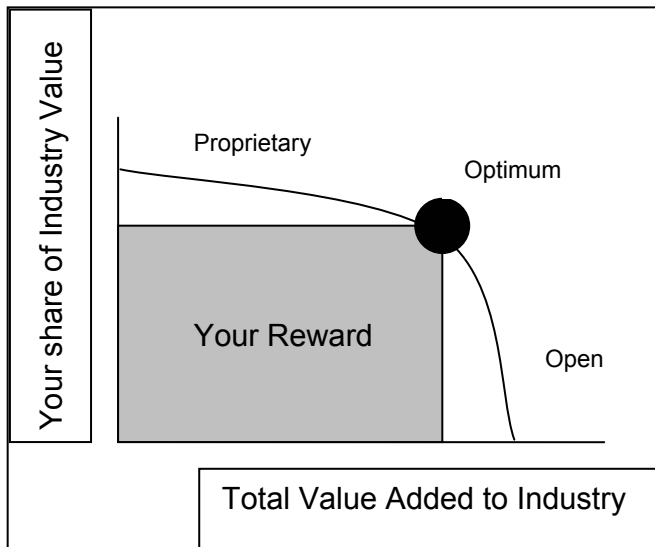


Figure 15: Openness versus control¹⁵⁴

It is likely that any sponsor of a new or emerging standard (at least implicitly) has this figure in mind when planning the strategic approach to competitors and potential partners on the market.

To illustrate actual examples of strategic choices of openness or control, the industry of computer operating systems are compared. As examples of three different openness policies, three major operating systems can be identified:

- Apple (Macintosh), who for a long time refused to license its hardware and software, hereby losing to IBM and its clones^{155, 156}.
- Windows, who were more open than Macintosh, but still control a number of key patents and technologies, which aren't available to anyone.
- Linux, which originated as a non-profit operating system and has become the embodiment of the open source movement.

¹⁵⁴ Shapiro & Varian, p.198.

¹⁵⁵ IBM and its clones would typically be referred to as Wintel computers.

¹⁵⁶ Shapiro & Varian, p.248.

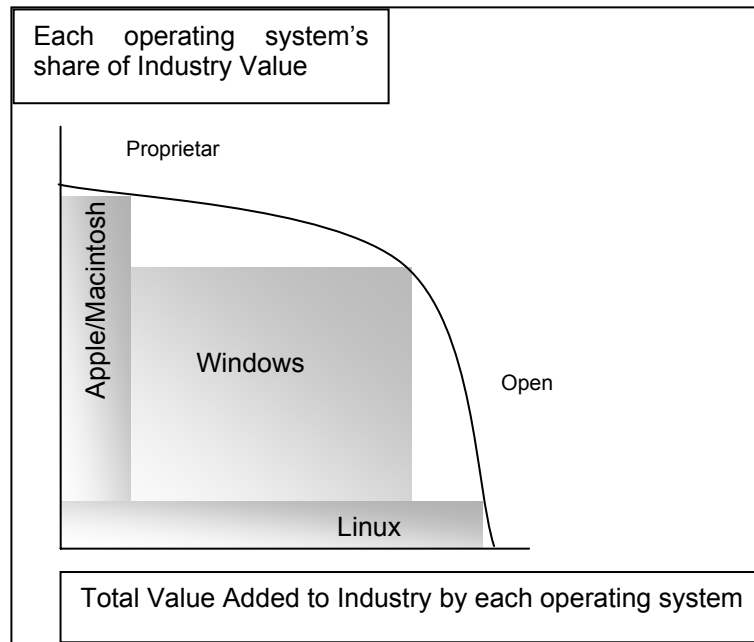


Figure 16: Strategic position of operating systems.

This figure is only an illustration of the three different strategies. Due to various reasons¹⁵⁷, the curve in the figure should probably be different for each operating system. Furthermore, there are properties of each operating system, which limit their choice of strategy. It could for example influence Apple's strategic stance that they needed a tight interplay between their development of hardware and software in order for it to function properly. Therefore, one can not state, that "if only Apple had chosen a more open strategy, they would have won". Another situation is the case with Linux that due to its open source character has no owner or sponsor per se. The open approach by Linux is therefore given beforehand.

5.1.11. Summary of Economics of Standardisation

The section of economics of standardisation has presented the important concepts forming the bulk of theory used in the analysis of the convergence process. The selected theoretical concepts can be seen as starting with the fundamental idea of standards being strong public goods, leading to the concepts of externalities in the adoption process and positive feedback, which appears when a standard has gained the upper hand in the competition with other standards.

¹⁵⁷ For example the reasons mentioned in footnote 153, but also the fact, that the operating systems were introduced at different times.

The size of installed bases and the tipping, which occurs once a particular installed base has reached a critical size, influences the fierceness of standards battles and emphasizes the importance of the strategic and tactical issues as firms' means of promoting their own technology in order to get the market to lock in and follow a development path based on their particular technology, which in this fashion establishes itself as the de facto standard.

These logics apply to the so called communication networks, but also, with less direct externalities, to hardware/software systems. With particular emphasis on this distinction between two generic types of systems, the whole set of theoretically postulated causalities and logics will form the basis of the further investigation and analysis.

The main theory buildings and their mutual relations from within the field of standardisation economics can be represented as follows:

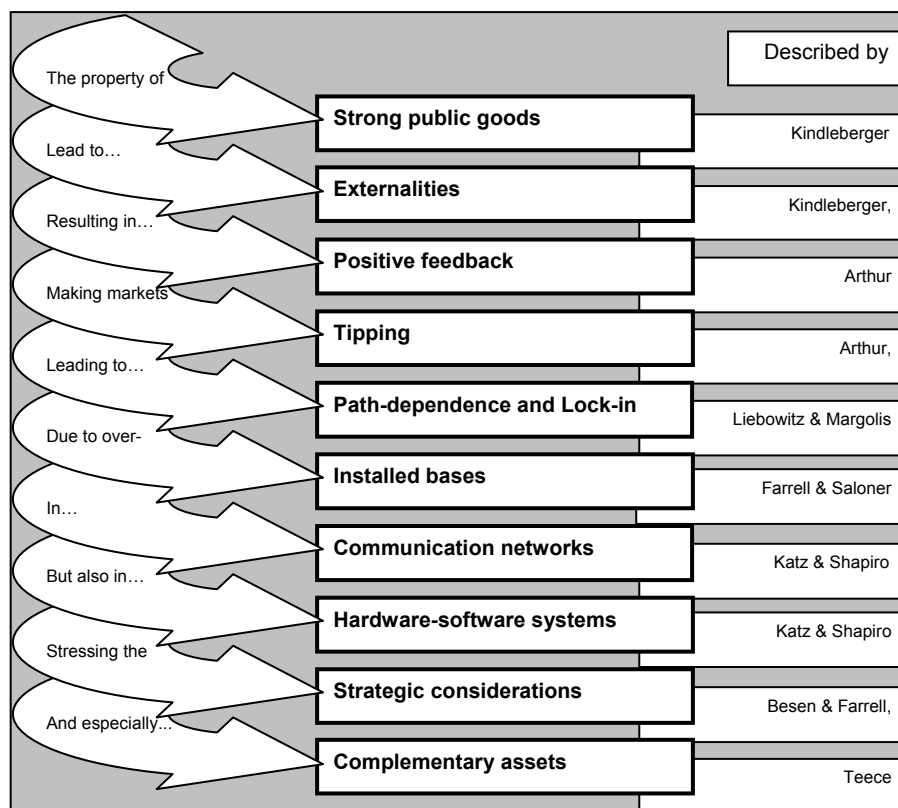


Figure 17: The theoretical framework of economics of standardisation.

This body of theory constitutes the bulk of this project's theory apparatus. However, relevant perspectives can be derived from other theoretical areas. Therefore, the

following sections present a number of theories, which serve to shed further light of the issue of convergence. In these sections, the relevance and eventual shortcomings of the supporting theories is described, their couplings with the standardisation economic theories are pointed out, and the need for development of further supporting theory is identified.

5.2. Economics of Innovation

The purpose of this section is to present a number of theoretical concepts supplementing the set of standardisation economic theories presented earlier. These ideas are concerned with the nature of innovations – i.e., among other topics, which market forms stimulate innovations, how one innovation influence others and how one system of innovations can replace an older one.

These theories do not constitute the primary theoretical framework of this project, but primarily serve descriptive purposes as well as answering the conceptual questions of how to properly define the converging areas. From this body of theory, a proper perspective of the areas of television, computer/networking and telephony are derived. With a proper descriptive term, the notion of “areas” can be abandoned in favour of a more precise term more matching the focus of this work. This section presents only the terms derived for the descriptive purposes of this report. A more elaborate description of the underlying logic of these terms can be found in the “Economics of Innovation” chapter of the appendix. Here is also a description of the term “reverse salients” which are used to describe particular drawbacks or problems, which induce changes in technology.

5.2.1. Systems and Sectors

A central purpose of this section is to clarify the ways, the three areas of television, telephony and computer/networking, are defined. It is obvious, that we are dealing with three areas, which until recently – i.e. until the process of convergence set in – were distinct, and now that they are in some way or another converging, we should be able to identify a suitable theoretical perspective of these areas. This exercise, however, is not merely a question of finding a suitable definition of these concepts. It is also a question of finding a relevant perspective on them among the ample body of theories available. Hereby, one can easier describe the processes and phenomena observed in a relevant context.

The separate areas can be observed as having their own sets of standards acting as the building blocks of the systems. In other words, the separate areas might be viewed as *meta-standards*, i.e. systems of standards or even “standards of standards”. The area of television, for example, consists of a large number of standards, ranging from specifications of transmission signals, programme coding and aspect ratio, all

ensuring, that a broadcast actually can be viewed by those having television sets and antennas or cables complying with the standards in question.

There are many terms describing the converging areas to choose from. Are television, telephony and computer/networking for example *markets*? Or would it be more suitable to categorize them as *branches*? Are they *sectors*? Or *systems*? They could also be termed *networks* or *technologies*. Alternatively, they could be described as belonging within certain *paradigms* or *trajectories*. Which term is most appropriate when examining convergence from an appliance perspective? And what are the implications of the choice of concept in terms of theory?

Just picking one term among those available is not sufficient. The choice of term implicitly points to a choice of model or theory. On the other hand, the economics of innovation is not the core area of theory in this project, so the choice of definition will not be subject to deeper analysis than necessary in order to ensure the relevance of the actually chosen term.

Among the many suggestions for a definition, an obvious candidate is the notion of *systems* as it is described by Thomas Hughes. This definition is especially appealing, since it incorporates the social aspects contributing to the whole system. This is particularly relevant when considering the focus area of this project: the private use of television, telephony and computer networking. Here, it is obvious, that the habits and interaction of users as well as the forming of groups among them has significant influence upon the convergence process.

Definition:

A technological system is a set of interacting components sharing a common understanding of how to solve problems and fulfil goals.

Definition 18: A Technological System¹⁵⁸ (a lexical definition).

The notion of systems in Hughes' definition is used in this Ph.D.-project to cover the converging areas. This is in accordance with the language of Katz & Shapiro, who use the term "system competition" to denote the competing areas with mutually incompatible standards. Though no reference to Hughes is found in the work of the latter, there is nothing suggesting a discrepancy in their understanding of the concept of system. Thus, the term and connected theoretical concepts are expected to serve the project's purpose.

¹⁵⁸ This author's own definition of "a technological system", based on Hughes' text. Even massive studies failed to produce a short and concise definition, so this, combined with the surrounding text will have to suffice.

Alternative views on how to properly define various areas of industries or markets have been put forward. For example, a definition of *sectors* has been proposed by Keith Pavitt¹⁵⁹, but this is hardly useful here, partly because it focuses on firms (especially manufacturing firms), partly because the notion of “sector” isn’t sufficiently well defined. What is needed for this project is a framework describing important components of the converging areas (the *systems* of television, telephony and computer networking when using Hughes’ model), and not least important, a framework which is able to take into account the behaviour of large groups of private users.

There is, however, a multitude of interpretations of the “sector” term. For the purpose of this work, no analytical definition will be given. The term “sector” is therefore used supplementing the term “system”, but referring rather to a business area than to a set of interacting components. “Sector” is often preferred in the following chapters due to the widespread use¹⁶⁰ and broad intuitive understanding of it.

In this dissertation, the term “sector” is used to denote a hitherto separate business area, easily distinguishable by having its own preferred infrastructure, its well-established organisation of information and communication, its classical preferred appliance and a set of inherent modalities in information and communication.

Definition 19: Sectors (a stipulative definition).

5.2.1.1. Defining the areas of telephony, television and computer/networking

The principles of technological systems as well as technological paradigms and trajectories apply to the three converging areas of television, telephony and computer/networking. As is shown in later chapters, different characteristics apply to each area. The nature of content and service, appliances, organisation, infrastructure and transmission of signals are sufficiently different among the three areas to use either term (system or paradigm/trajectory). To stress the importance of users in the process of shaping, the notion of technological systems is, however, better suited when referring to the areas in general terms. Hence the following definition.

The until recently separate – but now converging – areas of television, telephony and computer/networking are referred to as **technological systems** when the focus is on the interplay of its components, and as **sectors**, when applying a more broad perspective – especially that of a business area.

Definition 20: The three converging areas defined as systems and as sectors (a stipulative definition).

¹⁵⁹ Pavitt, 1984, pp. 343 – 373.

¹⁶⁰ The “sector” term is for example used by the European Commission without further definition in the title “Green Paper on the Convergence of the *Telecommunications, Media and Information Technology Sectors*...”

Expressed in terms of paradigms and trajectories (see the “Economics of Innovation” chapter of the appendix for a more elaborate description of these terms), the convergence process can still develop in various ways. The “true convergence” in the form of a *melting together* of the three systems incorporating properties of all three systems would resemble a “conservative” modification of paradigms¹⁶¹. By contrast, a migration by the services and content of television and telephony onto the appliances and infrastructure of computer/networking would imply a paradigm shift – a shift by the two “old” systems onto the paradigm of the new one.

5.2.2. Reverse Salients

Another important contribution from the theories of Economy of Innovation are the concepts, which describe the problems or drawbacks, which can lead to a change of systems (Hughes’ notion¹⁶²) or a paradigm shift (Dosi’s notion¹⁶³). While referred to as “unsolved difficulties” by Dosi, Hughes uses the term “reverse salients” to describe such a drawback of a system. This is interesting in relation to the convergence process, as such problems in the system of television stimulate the change of the system – either via “true” convergence – i.e. the adoption of computer methods and technology in the television sector’s appliances and infrastructure, or – which is a more genuine system change or paradigm shift – a migration of television content onto the appliances and infrastructure of the computer/networking sector. The outcome of the convergence process is not necessarily one of these two outcomes presented, but can be anything in between the two extremes of “mild” mutual influence between systems and complete migration.

The concept of reverse salients is adopted for use in this work. Further description of the concepts is available in the “Economics of Innovation” section of the appendix.

A “reverse salient” is a particular problem or drawback of a system, which pushes in the direction of a modification of the system or a switch to another system.

Definition 21: Reverse salient (a lexical definition).

5.3. Media, Information and Communication theories

The process of convergence is not only about the standards of products and services. Neither is it only about different systems and paradigms in competition. The very essence of these sectors is their ability to facilitate communication and consumption of information. Apart from standardisation and innovation theory, a *theoretical system describing communication and information consumption* therefore is necessary. A

¹⁶¹ Dosi’s article has no mentioning of any convergence or joining of paradigms.

¹⁶² Hughes, 1989.

¹⁶³ Dosi, 1982.

number of communication theory paradigms are available, from Shannon/Weaver's¹⁶⁴ mathematical theory to the more recent *Media Richness Theory* by Daft & Lengel¹⁶⁵. These constructions however do not fully encompass all relevant aspects of communication in converging communication. More promising is a *media taxonomy* by Hoffman & Novak¹⁶⁶, but though the taxonomy itself is useful and detailed, it was developed with electronic marketing in mind and thus lacks a theoretical construction relevant for the analysis of standards and convergence issues. Due to the obvious shortcomings of existing models, a new model tailored for the focus of this Ph.D.-project is developed in the "Information and Communication Taxonomy" chapter.

5.3.1. The OSI model

When contemplating the systems involved in convergence, it is obvious that they share a number of characteristics in the way they are structured. They all rely on a physical infrastructure – typically cables, antennas or satellites - for transmission of signals. They all have a set of rules specifying the signals running in the infrastructure. They all have appliances that are able to interpret these particular signals. And these appliances all have input¹⁶⁷ and output¹⁶⁸ interfaces. Furthermore they have typically been used for particular purposes in specific settings¹⁶⁹.

These properties of the systems point to a perspective of layers. Such a perspective can help ordering the different aspects of the converging systems into well-defined levels, at which the three different systems can be analysed and compared. In order to describe the possible directions of convergence, it is useful to look at the different levels at which convergence can occur. Convergence can take place not only by the development of new and different appliances (though this is the main focus of this project), but also in the sense that one communication infrastructure is used for content belonging to another sector, or that one sector adapts the technically superior infrastructure of another sector.

Having settled on a layered approach, one well-established layered model describing a communication system comes to mind. This is the OSI reference model proposed by Tanenbaum¹⁷⁰, who defines seven layers of a computer network:

¹⁶⁴ Shannon & Weaver, 1949.

¹⁶⁵ Daft & Lengel, 1984.

¹⁶⁶ Hoffman & Novak, 1995.

¹⁶⁷ E.g. a dial on a telephone, a remote control for a TV and a mouse and keyboard on a computer.

¹⁶⁸ E.g. a receiver on a telephone, a CRT tube and loudspeakers on a TV and on a computer.

¹⁶⁹ E.g. a telephone is typically used by one person, for work as well as leisure. A television set is often used by a whole family for leisure, and a personal computer has traditionally been used by individuals for work.

¹⁷⁰ Tanenbaum, 1981, p.15f.

- The *physical layer*, which is the copper wires or optical cables for the signals as well as the physical connections of network components and appliances.
- The *data link layer* is concerned with the type of network in use¹⁷¹, and controls the functioning of data flow, the rate of packets, correction of errors etc. This layer controls node-to-node communication.
- The *network layer* is responsible for addressing, switching and routing of packets.
- The *transport layer* takes care of segmenting messages at the source and reassembling them at their destination.
- The *session layer* manages the start, end and control of a session – e.g. a file transfer – between two computers.
- The *presentation layer* ensures that the syntax of the data is understood by the computers involved in communication, and also manages encryption and compression of data.
- The *application layer* has to do with the applications used by the individual operating the computer. This can for example be browsers or email applications.

Though this model is widely used in computer science, and thus would make the results of this Ph.D.-project more directly applicable to this particular branch of research, the OSI model will not be used due to a number of circumstances.

Firstly, it is obviously geared towards the computer sector with its separation of hard- and software – a distinction less identifiable in the telephony and television sectors. This would make the model difficult to apply to the latter.

Secondly, its approach is far more technical than this project. The physical layer and the application layer have relevance, but the intermediate layers are too detailed to be useful.

Finally, the OSI model seems ill suited to function as a framework of analysis of generically different communication forms¹⁷², as it focuses narrowly (but in great detail) on the technical aspects of electronic communication.

The idea of a layered approach is however useful, and the perspective of information and communication in the various converging sectors are inspired by an initial layered

¹⁷¹ E.g. Ethernet or Token Ring.

¹⁷² E.g. person-to-person two way voice communication (a phone conversation), organisation-to-population one way video and audio communication (television broadcast).

model developed as a part of this Ph.D.-project – a model that contains levels better suited for the particular focus of the project.

5.3.2. Communication Theory

A central promise of convergence is the possibility of sending and receiving information and communication in alternative ways. To properly analyse these promises, however, it is necessary to describe the characteristics of the information and communication that can take place in the various sectors.

In order to assess the viability of for example sending a tennis match over the Internet instead of the traditional broadcasting in the television system, one must clarify the nature of the information. Elaborating on the example, it can be observed that a tennis match viewed on television consists of moving pictures (video) and sound (audio). To broadcast this on another system, this other system must be capable of representing video and audio to the viewer. The computer, which is the typical appliance in the computer/networking sector, is capable of this, so what appliances are concerned, this is absolutely possible. Should one consider the telephony sector as a candidate for showing tennis matches, one would soon realize, that the typical appliance is incapable of this, as it has no means of displaying video. Hereby, one can conclude, that as far as the appliances are concerned, traditional television content can easily be consumed within the computer/networking sector.

Example box 1: A tennis match in alternative sectors.

Here, a theory or model that can break down the information and communication into its smallest components is needed. It should operate with aspects such as the *organisation* of the communicating parties¹⁷³, the aspect of *time*¹⁷⁴, the modality¹⁷⁵ and to a lesser degree the *context*¹⁷⁶ in which information consumption or communication takes place.

When searching for a model of communication, the so-called Shannon-Weaver model is often recommended. However, in relation to this project, this model has some of the same flaws similar to those of the OSI model. The Shannon-Weaver model has some relevance in the sense that it specifies concepts such as source, message, transmitter, signal, channel and receiver.

¹⁷³ E.g. is it one-to-one communication as in a traditional telephone communication, is it one-to-many as in a television broadcast?

¹⁷⁴ E.g. does communication take place in real time as is the case for telephone conversations and live TV broadcasts, or might it be delayed as with email?

¹⁷⁵ E.g. does the information or communication consist of sound, still pictures, video and/or text.

¹⁷⁶ E.g. in social relations (as television) or in individual work relation (as email).

*The information **source** selects a desired message out of a set of possible messages...The selected **message** may consist of written or spoken words, or of pictures, music, etc. The **transmitter** changes this message into the **signal**, which is actually sent over a communication **channel** from the transmitter to the **receiver**. In the case of **telephony**, the channel is a wire, the signal a varying electrical current on this wire; the transmitter is the set of devices (telephone transmitter, etc.), which change the sound pressure of the voice into the varying electrical current. In **telegraphy**, the transmitter codes written words into sequences of interrupted currents of varying lengths (dots, dashes, spaces). In **oral speech**, the information source is the brain, the transmitter is the voice mechanism producing the varying sound pressure (the signal), which is transmitted through the air (the channel). In **radio**, the channel is simply space (or the ether, if any one still prefers that antiquated and misleading word), and the signal is the electromagnetic wave, which is transmitted. The receiver is a sort of inverse transmitter, changing the transmitted signal back into a message, and handing this message on to the destination¹⁷⁷.*

These terms are useful when characterizing various forms of information and communication. But apart from this, the model offers little support to the questions of this project. It is, as stated in the original title, a *mathematical* model of communication, and has little to do with the communication systems and methods of today.

5.3.3. Media Theories

Other – more recent – theory buildings than that of Shannon and Weaver could also be candidates for suitable models. Recently, the Media Richness Theory¹⁷⁸ has received much attention as a framework for explaining the choice of communication form. Here, four criteria for classifying communication are defined:

- Immediacy (i.e. the dimension of time – whether feedback can occur immediately after a message)
- Multiple cues (i.e. the incorporation of gestures, facial expressions etc. in the communication process).
- Language variety (i.e. whether the language used can be adjusted to help the receiver to understand the message)

¹⁷⁷ Shannon & Weaver, 1949, pp 88-89 (bold added by this author).

¹⁷⁸ Daft & Lengel, 1984, pp.191-233.

- Personal source (i.e. the opportunity to signal one's feelings¹⁷⁹)

In the media richness theory, a number of communication forms are ranked according to their degree of richness, with a face-to-face communication as the reference standard – and defined as the communication form with highest degree of richness.

Media, the plural form of medium: *...a channel or system of communication, information, or entertainment...*

Definition 22: Media (a lexical definition)¹⁸⁰.

While undoubtedly interesting, the richness of media is not at the core of the focus of this project. The media richness theory is more concerned with the appropriate choice of communication form for a specific task than the technical possibilities of the converging systems. The basic need is a taxonomy describing the more measurable aspects of communication – whether it is based on text, voice, video etc. If, however a later study should be concerned with user's habits and patterns of information and communication consumption, the media richness theory might be a strong candidate.

The closest bid for a useful model is one developed by Hoffman and Novak¹⁸¹, who define a number of "objective characteristics of media":

- Person-interactivity (whether the medium allows persons to interact)
- Machine-interactivity (whether the user can interact with the appliance)
- Number of linked sources (describes the number of sources available or accessible to the user at any given usage opportunity).
- Communication model (describes how the communicating parties are organised – e.g. whether it is one-to-one or one-to many, many-to-many etc.)
- Content (describes what is in the information or communication in terms of text, sound, video etc.)
- Media feedback symmetry (describes whether the communicating parties have different bandwidths for sending information)
- Temporal synchronicity¹⁸² (whether communication takes place real-time or is delayed – as in a phone conversation versus an exchange of emails)

¹⁷⁹ A replication of facial expressions is often attempted in emails and chat by the use of so called "smileys".

¹⁸⁰ Merriam-Webster.

¹⁸¹ Hoffman & Novak, 1995.

¹⁸² Equals the "immediacy" criterion in "media richness theory"

Furthermore, the article by Hoffman and Novak orders a number of actually observed information and communication phenomena in a coordinate system with the x axis specifying the level of “personality” in the information or communication process¹⁸³, and the y-axis representing whether the process is dynamic or static.

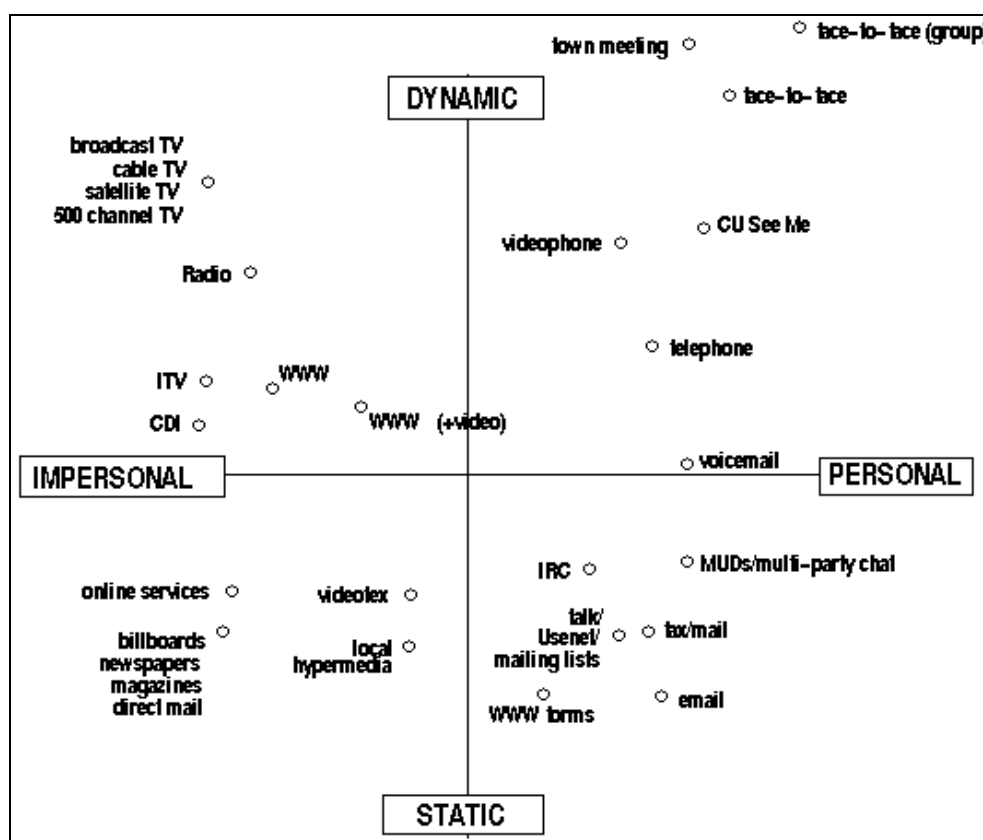


Figure 18: Media Typology Based Upon Objective Characteristics¹⁸⁴

Though this conceptual model originally was developed with the purpose of clarifying the environment in which electronic marketing and commerce takes place – and not as such is aimed at explaining convergence – it contains many of the parameters or characteristics relevant to describe, analyse and compare the converging sectors. Many of the parameters can be directly related to technical properties of appliances, infrastructure and signal standards of the converging sectors.

¹⁸³ Using the concepts of this Ph.D.-project, an impersonal phenomenon would fall into the category of “information consumption”, where a personal one would be categorized as “communication”.

¹⁸⁴ Hoffman & Novak, 1995.

Still, the Hoffman and Novak model is not perfectly suited for this Ph.D.-project. Therefore, a model and taxonomy, drawing heavily upon it, but especially dedicated the analysis of convergence is developed in a separate chapter, where relevant elements from existing models and theories are incorporated into a taxonomy of converging electronic communication.

5.4. Summary of Theory Chapter

This chapter has presented a number of theories, which are elements in the framework of analysis of the convergence process. The most important body of theory – coming from the field of Economics of Standardisation – is easily applicable to the research questions and the case studies. Likewise, the important body of supporting theory coming from the area of Economics of innovation is easily applicable, though it serves a number of mainly descriptive purposes of this project.

The lesser supporting theory bodies concerning media, information and communication concepts have proved to be less directly suited for the purposes of this project. Therefore, a separate chapter, “Information and Communication Taxonomy” is included for the purpose of mending this shortcoming of the combined body of theory and to reply the research questions concerning the information and communication characteristics.

5.4.1. Application of theory

Though the application of theory takes place on a broad level in many of the following chapters, various interesting relations and logics can be observed in the presented theory. These logics apply to the phenomenon of convergence in general – they need not be applied to any particular case study to be relevant, and indeed, they are pointed out in the sub-conclusions of all case studies.

Other – more case-specific elements of theory – are only described in single cases, but those, which have obvious and general relevance, are presented in the following:

First and foremost, the nature of *positive feedback* and its effects on the development of the products and services crucial to each case are described for each case study.

For *each sector*, it is relevant to define what the *installed base* – as mentioned on p. 72 – consists of. More specifically, it is interesting whether the installed bases (largely consisting of software) of the computer/networking sector are more transient than the more tangible installed bases of hardware in the television and telephony sectors.

Particularly interesting in this area of investigation is the *rigidity* of the relations between the complementary assets described on page 78. Depending on a number of properties of the systems, one can imagine differences in the *flexibility* of one asset to

work in conjunction with another asset. The computer/networking area could be expected to be superior in the field of flexibility, enabling its components to incorporate a wide number of products and services compared to the areas of television and telephony which must be expected to have more rigid couplings between core products/services and related assets¹⁸⁵. It is relevant in the *case studies* to *identify circumstances* that support this assumption – that the computers are more flexible, and furthermore account for the existing and possible future *complementary assets* and their relation to the basic services and products.

Users have *frequent opportunities* to *switch* between standards – as mentioned on p. 68, if the appliances have *short life cycles*. This might lead to a weaker lock-in in areas with short-lasting appliances (possibly the computer/networking sector) than in the areas with long-lasting appliances (presumably the television and telephony sectors). This could result in differences in path-dependence as mentioned on p. 72 – a difference that would be interesting to point out in the case descriptions.

No matter of caused by long product life cycles, the possible issues of 3rd *degree path-dependence* are relevant to look at, especially since the convergence process might serve as an opportunity to remedy the lock-in which might have taken place. The possible situations of path-dependence are therefore identified in each case study, and the existence of “opportunities of remedy” is discussed.

The use of the *appliances*, mentioned on p. 73 is highly important when one investigates the development going on within the convergence process – for example: with the addition of networking capabilities, is the computer *developing* from a true *hardware-software system* into a *communication network* type of appliance? If this is the case, the computer/networking sector might be subject to *stronger externalities* than when it was a pure hardware/software system¹⁸⁶. Hereby, the *lock-in* effects and *path-dependence* would be *stronger*, possibly leading to a *slower development* with less “quantum leaps” in innovation.

As mentioned on p. 77, the success of the computer as a household device might increase the importance of private “*support networks*”. It would be outside of the scope of this Ph.D.-project to investigate whether private support networks actually *are* emerging, but it seems fair to assume that they actually are – especially based on the massive support activity, which can be observed in newsgroups (Usenet). This leads to even *greater feed-back* in purchase decisions, as the availability of a support network will be of great importance when choosing between standards.

¹⁸⁵ e.g. PAL signals for PAL TVs, ISDN phones for ISDN connections

¹⁸⁶ The network effects of a hardware/software system being less direct (as pointed out on p.5), it must be assumed that they are weaker than the direct ones in a communication network.

The study furthermore searches for reverse salients” which can induce changes or switches of a system (These are the so-called “unsolved difficulties” in Dosi’s notion). This is done by describing the weaknesses of one particular sector – especially when the particular reverse salient figures as a strength of the other sector.

The case studies will incorporate the above topics by commenting on them in sub-conclusions, containing the following issues:

- Description of the positive feedback processes and their effects.
- Description of hardware/software system and communication network characteristics.
- Identification of flexibility issues.
- Identification of path-dependence and opportunities of remedy.
- Description of the typical nature of the installed base of each sector.
- Identification of the relevant complementary assets.
- Identification of reverse salients (or unsolved difficulties).

The topic of “differences in life cycle lengths in the various sectors“ is not included in the list, but is looked upon in “Signal, Interconnection and Content Standards” study as well as in the “The TVPC Case Study”. These are not the only tasks in the case studies. The fundamental guide in the case reports remains the research questions formulated earlier.

6. Information and Communication Taxonomy

This chapter is the first step in the development of a descriptive tool for categorisation and analysis of electronic infocom phenomena, and represents a suggestion of a suitable taxonomy of these phenomena.

In order to properly examine the various forms of electronic communication and information consumption observed today, a systematic categorisation of the observed communication forms and their various properties is necessary.

Based on such a framework, in-depth research can depart from a well-defined starting point, and it will be clear, where in the landscape of convergence the research is focused.

Other attempts to create similar infocom taxonomies¹⁸⁷ are plentiful, but a coherent taxonomy covering the convergence area, its communication and hardware is still to be developed.

6.1. Steps in the process

The chapter takes off with touching upon the topics, which should be contained in a useable taxonomy for electronic communication. From here, it moves on to describing a number of commonly observable electronic communication *phenomena* in the three classic sectors of electronic information and communication.

Then, a number of objective *parameters* applicable to all phenomena of electronic infocom is presented - ordered in higher level *dimensions*, followed by an ordering of the earlier described phenomena in matrixes or tables, providing a morphological overview of the landscape. The cells in the matrixes (i.e. the detail *properties* of the phenomena) are described, and examples of relevant real life convergence processes are given.

Finally, the forces and shortcomings of the taxonomy are touched upon, followed by suggestions for future improvement.

6.1.1. Components of the taxonomy

Initially, convergence is regarded as a process taking place between three sectors of electronic communication (Television, Telephony and Computer/networking). Accordingly, communication phenomena originating from each of these sectors are

¹⁸⁷ See e.g. "A Taxonomy of Internet Communication Tools" by Byron Long and Ronald Baecker, University of Toronto, (online reference: <http://www.dgp.utoronto.ca/people/byron/webnet/Taxonomy.html> - link active per 000321)

identified. These phenomena are then described with regards to their relevant properties. Though this Ph.D. project focuses on the convergence between television and computer/networking, telephony is also included in the taxonomy in order to make it valid as a tool for description of convergence phenomena in general.

When describing the identified communication phenomena in a complex environment, perspective can be gained by categorising the topics subject to description. Therefore, the parameters are ordered in higher-level dimensions. The choice and placement of the parameters is based on a common-sense perception of their nature, but future development of the taxonomy can change the number, nature and organisation of parameters and dimensions.

To give a thorough picture of the converging communication phenomena, a number of relevant parameters for further description must be identified. These parameters - though objective in nature - relate to the way, in which the user perceives the communication process. Examples are the properties of user interaction with the communication device (be it a stand-alone appliance or a computer application), with regards to the way, the user operates the device (input parameters) and the way the device presents the communication (output parameters).

The taxonomy model is displayed as a matrix with the communication phenomena arranged vertically and their various dimensions and parameters arranged horizontally. The fields of the matrix represent a combination of a particular set of parameters and phenomena. The content of each field is the so-called properties of the phenomenon with regards to the parameter in question. Due to the great amount of variables in the matrix, it is presented as a number of sub-matrices – one for each dimension.

Before actually sketching the matrices according to the framework presented above, a more thorough description of the elements of the taxonomy is presented in the following.

6.2. Information and Communication Phenomena in the Taxonomy

This section presents a selection of communication phenomena currently observable. The list is not exhaustive, and as new forms of communications emerge, they can be included in this presentation.

For the purpose of providing an overview of the communication landscape, each communication phenomenon is presented shortly, only describing the most important properties. More thorough analysis of the various phenomena will not be found in this chapter. In e.g. case studies, the properties of the various communication phenomena can be elaborated upon to the extent suitable for the analysis. Here, this overview provides a set of common terms and perspectives providing coherence in later case studies.

In the following, the "service" term is used frequently. Therefore, it is appropriate to give a definition of this term.

Many so-called definitions of service are not definitions as such, but merely a presentation of properties¹⁸⁸ of the service in question. Rather than selecting a definition not quite fitting the usage of the term in this dissertation, the following definition is stipulated:

Services are the actions necessary in enabling communication and exchange of information, provided by parties external to the end users.

Definition 23: Services (a stipulative definition).

The above definition implies that:

- Services are not physical (they are not the infrastructure or the appliances).
- They are not software (they are not the applications or operating system).
- They are not content (such as a movie or news programme - but *delivery* of the movie would be a service).
- They are not the end user's selection - e.g. clicking a link or dialing a number on the phone (hence the "parties external to the end users" part).
- They are not the generation of the content of interpersonal communication (that is taken care of by the end users themselves).
- ...but they could well be the real-time assembly of different sorts of information into a whole, which is desired by the end user (such as a web portal or the hybrid service described in the TVBoost proof-of-concept prototype).

6.2.1.1. Television

The TV set is a comparatively old and well-known form of communication. Originally rising from experiments in the beginning of the 20th century, television evolved into a very powerful medium during the 1950's and forward.

Most people have a good idea of the meaning of the terms television, telephony and computer/networking. In this chapter, the three concepts are defined according to these conceptions. It should be noted, though, that one of the basic ideas of this Ph.D. project is to look beyond these three definitions, as they might make little sense in a

¹⁸⁸ An example is the UMTS Forum's distinction between services and applications. "Services are entities that services providers may choose to charge for separately" – an example of the usage of this distinction can be seen at www.umtsarea.com/download/report13.pdf (link active per 030226)

convergence process, whereas the properties presented in this taxonomy are better suited.

Television: A one-to-many form of real-time consumption of information, mostly by means of sound and moving pictures, often consumed in groups under relaxed circumstances on dedicated appliances.

Definition 24: Television (a stipulative definition).

Television is characterised by being a one-to-many form of communication, meaning that the user can only receive content, not deliver it. The content suppliers were originally state monopolies, and this trend is still present, as content suppliers today still are large in comparison with content suppliers of e.g. telephony and web pages (who are often single individuals).

Compared with telephony and - until recently – computer/networking; television provides a high degree of modality. A television set is able to display moving pictures, text and sound. Since the sixties, colour picture became a widely adopted improvement, and in the late seventies and early eighties, modality was further increased by the introduction and adoption of stereo sound.

Today, a television usually is operated via a remote control. This in combination with the relatively large size of the screen, makes it possible for a group of people to watch the same programme together. Television is therefore often used in a social context - with a whole family watching it together.

Television was originally distributed as analogue radio wave signals sent and received via antennas. Later development has added cable distribution and satellite as ways of delivering signals.

The content of television broadcasts is primarily appeals to larger audiences - examples are news, movies, live sports transmissions etc. The increase in channels has however lead to a larger proportion of "thematic" channels for smaller audiences with specific interests.

Digital television is currently under development. The final shape is yet to be decided, and considerable differences exist between the various geographically separate versions.

An interesting question is why television became a one-to-many, one way, mass communication system instead of e.g. a one-to-one, two-way device as the telephone

did. This topic is further analysed in "The Shaping of Television"¹⁸⁹, which can be found in the appendix.

6.2.1.2. Teletext

Teletext is a service consisting of text and very primitive graphics. It is sent alongside the normal television system in the so-called vertical blanking interval or VBI. This means that the teletext information takes up no extra space, as the VBI originally was void of information.

The content primarily is news and TV programme guides. The user navigates the teletext pages with the television's remote control.

Teletext was developed in the late seventies and early eighties and an improved digital system is currently under development.

6.2.1.3. Radio

Radio is a household name for sound delivered via radio waves. The radio typically delivers news and entertainment via transmitting respectively receiving antenna. Lately, cable television networks have begun delivering radio signals.



Figure 19: Radio - a one-to-many, real time communication phenomenon.

¹⁸⁹This report can be found as a separate entry in the appendix.

Initially delivered by national monopolies radio showed the same tendency as television: Content suppliers were few and large. Over the years, smaller radio stations have emerged. In comparison with the television market, the radio market is far less oligopolistic.

As opposed to television, radios have been mobile for decades. This undoubtedly has lead to a pattern of use differing considerably for that of television.

6.2.1.4. POTS (PSTN) Telephone

The telephone was initially used for interpersonal communication. It was originally - and still primarily is - a voice based one-to-one communication medium. The communication device is a single purpose device (the "phone").

| |
|---|
| Telephony is two-way, real-time voice-communication. It traditionally takes place with specialised appliances over circuit-switched networks. |
|---|

| |
|---|
| Definition 25: Telephony (a stipulative definition). |
|---|

Lately, further functionalities have been added to the telephone. Examples are loudspeaker and microphone enabling two groups of people to communicate from separate locations. Over the years, the telephone service providers have introduced various information services. Conference services have enabled larger groups to engage in verbal teleconferences. Though expected for several decades, no video telephony system has been successful so far.

6.2.1.5. Mobile telephony

Originally, mobile telephony offered the same service as stationary telephony - apart from the mobility issue. During the 1980's mobile phones were very bulky, and not suitable for being carried around constantly - as the mobile phones of today. Mobile phones were wireless and battery powered - and as such mobile - but they were considerably larger and heavier than a stationary telephone.

With the coming of digital mobile telephony (in Europe represented by the shift from NMT to GSM) opened up for the possibility of additional services over the same network - most noticeable the SMS system described later.

Most mobile telephony takes place via terrestrial transmission networks. These are divided into so-called cells, hence the term "cellular telephony".

6.2.1.6. SMS

Short Message Service - or SMS is a text based message system functioning under the GSM mobile telephone system. It allows users to send short messages to one another.

One of the important benefits of SMS is the fact, that it need not be received instantly. It can be stored at a SMS message centre until the recipient's phone connects to the network.

6.2.1.7. WAP

The Wireless Application Protocol (or WAP) is a service aiming at enabling mobile users to access information services. WAP is intended to deliver services similar to the Internet - i.e. primarily text, but also images and sound. However, WAP is developed specifically for use from mobile terminals. By the start of year 2000, the first WAP enabled mobile phones have appeared.

WAP is designed to work with most wireless networks, e.g. GSM, CDMA, PHS and TETRA. This means, that WAP is not designed specifically for a single mobile telephone standard, but potentially can become a worldwide standard.

6.2.1.8. Telefax

Telefax (or Facsimile - or simply Fax) is a system running over the POTS network, making it possible in one operation to scan a document, call the recipient, transmit the scanned document and having it printed on the recipient's fax machine. Fax has until recently been possible only with dedicated fax machines¹⁹⁰, but lately, software has been able to link scanner and printer to a computer with modem or similar communication device - thus turning the computer into (among other things) a fax machine.

To receive a fax, the fax machine has to be online. No further action by the recipient is necessary. Faxes are printed on paper, usually in monochrome/black and white.

6.2.1.9. WWW

The World Wide Web - or WWW - is the best known among the various communication forms of the Internet. The content of the WWW is web pages, located on web servers from where they can be accessed via the Internet - which is basically a large computer network.

The web pages in their basic form contain text and graphics, but many other forms of content has appeared on the web. Sound, moving pictures and 3D models are often used to further increase the modality of web pages.

¹⁹⁰ A fax machine is a classic – and often used – example of a good that is subject to externalities. The imaginary first person in the world to own a fax would have no one else to communicate with, and hence had no use for the device. In reality, the first purchases of fax machines were probably done in a coordinated manner – e.g. a fax machine for each regional office of a multinational corporation.

The Internet is a packet-switched network on which information and communication in real-time as well as delayed can take place, often by means of text and graphics, usually on a computer.

Definition 26: Internet (a stipulative definition).

The web pages are provided by government institutions, companies, private individuals - everybody with a computer and Internet access can provide content to the web in the form of web pages. Because web pages are stored on web servers, the provider needs not take any action when a content consumer uses the web pages.

6.2.1.10. Email

Electronic Mail - or Email - has been in use longer than the Internet - although the emergence of the Internet and enormous growth of the Internet during the 1990's have boosted the adoption of email considerably.

The main content of emails is text, though development has allowed images, graphics and sound to be part of the email content. Furthermore, files can be attached to emails, making it possible to transport programmes, documents and other forms of information.

Email basically works as traditional written mail - but with different media and distribution channels. The email is composed on a computer and sent via a computer network to the recipient, who typically reads it on the computer monitor.

The email is received by and stored on a mail server, so the recipient does not have to be online to receive the email.

6.2.1.11. Newsgroups

Discussion groups or Newsgroups are quite similar to emails with regards to content. However, the forum is quite different. Instead of interpersonal communication, the messages appear among the messages of other subscribers¹⁹¹ to a particular newsgroup.

This way, several so-called "threads" of discussions can run simultaneously in a newsgroup. It is possible for any participant to introduce new topics or comment on running threads.

¹⁹¹ The term "subscriber" can be misleading. To subscribe to a newsgroup, someone has only to set one's news server to download the discussions in the newsgroup, to which one wants to subscribe.

Like emails are stored on mail servers, newsgroups are stored on news servers. There are several thousand different newsgroups with each their particular topic. Due to this large amount, the operators of news servers often decide only to carry a limited number of newsgroups on their servers, thereby excluding others.

Like in the case of emails, the main content of newsgroups is text-based messages. However, images (and to some extent movie and sound files) are also displayed in newsgroups - some of which are specifically created for the purpose of picture trading.

As for emails, the communicating parties need not be online to have a conversation going. However, news servers usually delete messages once they are one or two weeks old, so compared to emails, some degree of frequent attention from subscribers is necessary.

6.2.1.12. Chat

Chat is a communication between two or more (rarely over 20) participants based on text only. To enter a chat session, the user needs a computer equipped with modem or similar communications device. As in the case of newsgroups, there is a large number of chat fora to choose from.

Chat facilities are often integrated in websites - and usually dedicated a particular topic of interest.

Chatting is a real-time form of communication. Comments, questions, answers etc. are typed and sent in quick succession. In this respect, chat is quite similar to a traditional verbal conversation - hence the name.

6.2.1.13. IP Telephony

In the late 1990's, telephone conversations became possible via the infrastructure of the Internet using the Internet Protocol. This had a number of advances over traditional circuit-switched telephony - especially the due to the favourable interconnect agreements of Internet operators leading to the signal being transported free of charge most of the distance between the communicating parties.

IP-telephony basically comes in two forms. One form is almost transparent to the user in the sense, that the traditional telephones are used - all the caller has to do is selecting a telephone/internet gateway, for example by dialling a certain prefix. Alternatively, IP-telephony can take place with computers as the user interface. Here, additional modality can be added to the conversation in the shape of video, shared whiteboard facilities and chat. This form of IP-telephony is also suitable for net-meetings between larger groups of people.

6.2.1.14. Webcam

Webcam can be defined as a piece of hardware as well as a form of communication - the latter definition is the one relevant here. The principle of webcam is having a video camera (special cheap versions for computers exist) installed on a home computer, sending a constant stream of still images or moving pictures (and in some instances also sound) onto the Internet. The images or movie is then typically shown on the webcam owner's homepage, where it can be seen by whoever might be interested.

Many of the webcams are in use on sex-oriented websites¹⁹² - however other uses can be imagined: Remote teaching, surveillance etc. At present¹⁹³, webcams are only practically possible on stationary computers with fixed Internet connections.

6.2.1.15. Games (and other computer programmes)

At first glance, one might think that the games and various applications such as spreadsheet, word processing, computer games etc. do not actually belong in a description of information and communication forms. And it is true, that many applications and games primarily are used by one person only interacting with a computer - not necessarily with other humans.

However, especially computer games display characteristics making it perfectly acceptable to define them as communication phenomena. The computer games' most noticeable role as a communication system might be found in the field of shared virtual spaces. Attempts to develop systems offering common virtual spaces have been many, but however with limited success. The development of networked computer games - especially first person shooter games - have given users from widely separate geographic locations the opportunity to interact in a shared virtual space. It is interesting to note that the simple, one person computer game has evolved into a shared virtual space with much greater detail and opportunities of human-to-human interaction than the most of the systems originally developed specifically with this purpose in mind.

In comparison with practically all the other forms of communication mentioned here, computer games display an immense richness in the area of modality. Moving picture clips and 3D-graphics in high resolution true colour are commonplace in the field of computer gaming. Further adding modality, stereoscopic vision is available in a large number of games. Surround sound (often in proprietary forms - as e.g. Creative Labs' "Environmental Audio") plus tactile input in the form of force-feedback joysticks and similar control devices increase modality even further.

¹⁹² 000314: <http://www.whatis.com/>

¹⁹³ March 2000

Also with regards to the user's interaction with the computer, gaming contains a wide array of possibilities. Control capabilities as keyboard, mouse and joystick are supplemented by yet more exotic control devices. Several games and other computer programmes make use of voice control - enabling the user to control the computer by means of speech.

The communication phenomena presented above do not provide a complete list of electronic communication phenomena¹⁹⁴. Phenomena as e.g. ICQ, mailing lists and virtual clubs have not been described, as the aim of this taxonomy is to draw the big lines in the convergence landscape. The taxonomy however has ample room for inclusion of whatever present and future electronic communication phenomenon one could desire.

6.2.1.16. P2P File Sharing

A recent¹⁹⁵ phenomenon in the information exchange field is the Peer-To-Peer (or P2P) file sharing applications. Installed on individual computers, they allow the user to search and download files from other users connected to the same network. It is often expected by the community of the service that users in return for downloading make files available. E.g. the Kazaa file sharing software has a rating mechanism, ensuring that users that offer much material are prioritized higher in download queues.

File sharing applications are especially interesting due to the fact that they come in various flavours with regards to the degree of centralization – or what is referred to as the forum symmetry later in this chapter. In all instances, the actual files, which are subject to sharing, are located at the users' computers. With regards to the searching and indexing functionality, however, there are certain differences¹⁹⁶. Where e.g. Napster has a centralized database within which searches are carried out, Gnutella is a purely distributed service with no such central hub.

While file sharing as such is perfectly legal, file-sharing systems are often accused of being developed and used with illegal copying of copyrighted material in mind.

6.3. Dimensions of Phenomena

The basis of the taxonomy is a set of dimensions that are important in relation to the nature of the various electronic communication phenomena. These dimensions are results of reflection on the systems in existence and the information consumption and communication actually taking place on them. With the phenomena identified in this

¹⁹⁴ The main parts of this taxonomy were developed in March, 2000.

¹⁹⁵ P2P file sharing is introduced late in the work on this taxonomy (in March 2003). It is included because of its very fast adoption and controversial nature – often seen as a tool for violating copyrights.

¹⁹⁶ Aberer and Hauswirth, 2002.

taxonomy, the dimensions are suitable. Whether they will be suitable for every imaginable future manifestation of infocom is not certain, but due to their fundamental nature, the dimensions stand a good chance of being usable for describing information and communication in all its conceivable forms. The dimensions are:

- Appliances - Concerning properties of the communication device of the user(s)
- Interactivity -Concerning the users' degree of control or influence on the communication process.
- User Interface - Concerning the user's means of interaction with the device.
- Organisation - Concerning the structure of - and relations between - the communicating parties
- Transmission - Concerning the technical way, information is transported between the communicating parties.
- Time - Concerning aspects as simultaneousness of communication.
- Usage scenarios - concerning physical aspects of the context in which communication takes place.

The columns of the sub-matrixes shown later contain the detail parameters necessary for sufficient descriptions of the dimensions and phenomena. The detail properties are inspired by the "Objective Characteristics of Media" model developed by Hoffman & Novak¹⁹⁷ - where the "characteristics" of the Hoffman/Novak model are equivalent to the "parameters" of this taxonomy¹⁹⁸.

The Hoffman/Novak model is developed primarily with research in e-commerce in mind. For the purpose of analysing the innovation potential of the various converging sectors, more detail must be added to the parameters of the model, hence the division into dimensions containing parameters of greater detail.

At the same time, the model is reduced in number of phenomena. This is due to the fact, that the focus here is electronic information and communication. For simplicity, the non-electronic forms (as e.g. newspapers) are left out of the model - though they still display characteristics relevant for comparison of communication forms.

¹⁹⁷ Hoffman & Novak, 1995.

¹⁹⁸ It would be nearby to simply adopt Hoffman/Novak's "characteristics" term, but it is somewhat misleading talking about the characteristics of a phenomenon not yet analysed. The proper way to go is rather to define a set of parameters - and then talk about the characteristics with regards to a certain parameter. To avoid confusion, this taxonomy uses the term "property" for what could be termed characteristics. An example could be modality, which in term is a *parameter*, while moving pictures could be a particular communication phenomenon's *property* within this parameter.

The taxonomy proposed here is - as the Hoffman/Novak model - limited to describing objective properties of the communication phenomena. Hereby, no empirical analysis will be necessary to secure the validity of the taxonomy as a descriptive tool. Later research in convergence phenomena might well include more subjective properties and thus actualise the need for empirical foundation.

6.3.1.1. Appliances

The appliances dimension is concerned with the "gadgets" or hardware used for the various forms of communication. In the convergence landscape a wide array of hardware - ranging from stand-alone appliances like the telephone to multi-purpose machines such as the computer - are in use.

An obviously important property of a piece of hardware is its flexibility or "multi purposedness". This flexibility or lack thereof must be expected to influence the possibilities of innovations within the services intended for this particular piece of hardware - that is, unless the innovation sequence is reverted, meaning that a piece of hardware is developed specifically for a particular form of communication in a "market-pull" fashion.

6.3.1.2. Interactivity

When communicating or consuming information, the user interacts in two dimensions. Basically, the user interacts with other persons - as in e.g. a phone conversation, or interacts with a system of hardware and software - as e.g. when watching television. These two forms are referred to as *person interactivity* and *machine interactivity*.

Then, the user interacts with the appliance described previously. This form of interaction represents the user's influence on or control of the appliance. In the situation where the user does not communicate with other persons, this is the user's means of influencing the outcome of the communication process.

The possibilities of human interaction heavily depend on the nature of the appliance used for communication. Here, the sub-matrix describing user interfaces is closely related to the degree of interactivity. One might even say, that interactivity depends on the user interfaces plus the design of the content (whether it is broadcast TV programs, software or other forms of content).

6.3.1.3. User Interface

This dimension covers the borderline between user and machine. It covers both the input and output capabilities of the appliance. These properties to a large extent contribute to the user's experience of interaction.

The *control capabilities* are the user's physical means of controlling what is happening. They are the "control buttons" of the appliances. With them, the user initiates a communication process, or at least - when for example picking up a ringing phone - decides to participate in one.

The central properties of the output capabilities need description beyond merely mentioning their basic properties (as e.g. defining the output device of a radio as a loudspeaker). Though output capabilities can be divided into main categories depending upon which of the human senses they influence, a more detailed distinction is necessary.

Visual output can be described from more than one perspective: one can distinguish between monochrome, greyscale and colour pictures, between monoscopic and stereoscopic vision, but also based upon the nature of the information: whether it consists of e.g. text, still images, moving pictures, graphics (such as charts, diagrams etc.) or a combination thereof. Here, the need for the earlier mentioned distinction between hardware and content is obvious, but to provide a basic overview of the research area, using the term *modality* as covering both hardware and content is sufficient.

6.3.1.4. Organisation

Having earlier described areas where hardware is of considerable importance, we now move on to a dimension, where its role is less evident. The topic here is the organisation of the communicating parties - covering several sub-topics:

The *number of linked sources* is described by Hoffman & Novak as "describing how many sources of content are readily accessible or available to the user at any given usage opportunity."¹⁹⁹

Communication modes illustrate the number of people involved in the communication process - and their distribution with regards to their roles as information providers or receivers. Bowles²⁰⁰ identifies four modes:

1. One Alone
2. One to One
3. One to Many
4. Many to Many

¹⁹⁹ Hoffman & Novak, 1995.

²⁰⁰ Bowles, 1995.

Forum/audience size refers to the number of recipients potentially interested in the information. A football match for example usually attracts many viewers, while a personal phone conversation ideally is of sole interest to the communicating parties. Here, the problematic of a division of the views into a hardware plus a content view is evident, because the number of potential recipients undoubtedly depends on the nature of the content, a consideration carried further in the “The Hybrid Communication and Information Case Study”.

The *forum symmetry* property is largely inspired by the definition of Hoffman & Novak:

*Media feedback symmetry refers to whether different parties in the communication process employ differing media bandwidths for sending information. For example, in an Interactive CD (CDI), feedback is asymmetric as the CDI sends high bandwidth information, but the consumer sends low bandwidth information. From the consumer's perspective, this facilitates interactivity because a few simple cursor, mouse or joystick movements produce dramatic modifications in the environment. When there is symmetric media feedback, all sources in the communication process employ the same media bandwidth for sending information, for example telephone, mail, and face- to-face communication.*²⁰¹

However, the above definition has to be widened somewhat for the purposes of this project. Forum symmetry also covers less technical issue as e.g. the moderator's possibility of censoring a newsgroup or mailing list, the viewer's lack of influence on the programme portfolio of a TV station - issues deciding the "power balance" of the communication process.

6.3.1.5. Transmission

Described in non-technical terms, it can be said that, depending on the *casting scope*, there are two fundamentally different ways of transporting information electronically.

One way is to distribute the signal to every potential recipient - i.e. everyone who has the necessary appliances and connections. This can typically be seen within the field of television (and radio), where everybody can receive and watch (or listen) to the programme. That is: unless some scrambling has been applied to prevent segments of users from accessing the information. This however does not mean that the excluded recipients do not receive the signal - only that they are unable to decode it. Distributing to every potential recipient is usually referred to as "Broadcasting"

²⁰¹ Hoffman & Novak, 1995.

The other way is only delivering the information to those interested²⁰². This is possible due to the transmission system's ability to direct the information to particular locations. These systems are in use in the telephony and computer network sectors - however with different technologies providing the exact delivery - the exact functioning of these systems (with the explanation of terms such as packet or circuit switching, routing etc) will not be described here.

For illustrative purposes, the first transmission system can be seen as a large network of water pipes. In the broadcast situation, there are no valves in the system, and once water is pumped into it, everybody has access to water. The selective version, with its specific delivery of information is comparable to a system with the valves necessary to lead the water to its intended destination.

Another important aspect is whether any *switching* or *routing* takes place during the communication or delivery of information. Typically, a TV network uses none of these methods – simply pouring information into its pipes, while telephony traditionally is based on a circuit-switched line, dedicated to communication between the involved parties, no matter whether any communication is actually taking place. On computer networks, including the Internet, information is divided into packets and routed to their destination.

6.3.1.6. Time

The dimension of time contains a central parameter in communication. It has to do with the simultaneousness of information - illustrated e.g. by the difference between email and telephone. In the email communication a reply is not necessarily required immediately, but can wait until the recipient logs on to his or her mail server. In a phone conversation, the situation is completely different. Both parties have to be "on-line" to carry out the communication, and the sender's articulating a sentence and the recipient's hearing it happens almost simultaneously.

6.3.1.7. Usage scenarios

This dimension describes not the appliances in specific terms, nor the nature of the communication itself, but the context in which the communication process takes place. To keep this taxonomy objective, preferences of the users will not be described here. Neither will the otherwise relevant consideration of "ease of use" concerning e.g. the difficulty of booting up a computer compared to the relative ease of switching on a TV set to get a quick overview of current programmes.

²⁰² This is only the case in the ideal world. Practically everybody with an email account has had the questionable pleasure of receiving junk email.

The first parameter, *number of simultaneous users on one terminal*, concerns the social context of the communication process - whether the communicating parties are carrying out the communication process individually (in a geographic sense) or in groups. Determinants of this parameter can be found in appliances (e.g. screen size - a large screen would allow more users to watch) as well as in the nature of the communication process (e.g. a private email of little interest to others than sender and recipient).

The second parameter, *mobility*, has to do with the size of the appliances as well as the nature of the physical infrastructure transmitting the information. A light and compact communication device is obviously more mobile than a large and bulky one. A wired device is likewise less mobile than a wireless one. But also modality comes into play here, as some human senses are more expendable in given situations - a car driver can for example still drive a car while listening to a radio broadcast, but hardly while watching television.

6.3.2. Interrelations between dimensions

With the greater detail added to the Hoffman/Novak model, there will inevitably be some overlap among the detail parameters of the sub-matrixes. This does not indicate redundancy in the model as such, but rather it represents interrelations, causal relations and correlations between the parameters.

For example, a certain coherence between Audience size and symmetry - which is why they are categorized as Fora dimensions - can be observed. One explanation to this phenomenon is that larger fora usually tend towards one-way communication - the sheer complexity of involving larger numbers of participants in dialogues would make many-to-many communications in larger fora impossible. Many-to-many communication in smaller groups is much more manageable.

Similarly, an interrelation can be observed between communication modes and immediacy: Many-to-many-communication is most likely in situations of non-immediate communication (due to the difficulty of managing a multitude of simultaneous participants).

Another example of interrelation among detail parameters is broadcast being most appropriate in immediate communications to large fora, due to its inherent hardware and usage scenarios: the large screen of a TV set is easier to view by a whole family than the small monitor of a computer.

6.3.3. Content or hardware

In the landscape of electronic information and communication, specialised appliances have traditionally been dominating. Examples of this are plentiful: Televisions solely developed for TV-broadcast reception, telephones solely developed for one-to-one speech communication, etc. Accordingly, the need for a distinction between the appliance and the content intended for it has not been obvious.

With the coming of the networked computer and the wide array of information and communication forms it offers, this distinction has become highly topical when attempting a classification of infocom phenomena. However, in this proposed taxonomy, hardware and content is described without any particular distinction. At later stages of research, however, a sharp separation of hardware vs. content properties will be necessary.

The Hoffman/Novak model of objective characteristics of media is mainly focused on content properties. A later development of the taxonomy presented here could very well consist of a separation of hardware respectively content parameters in the taxonomy resulting in a return to the pure Hoffman/Novak model supplemented with a model of hardware properties.

6.4. Properties of Phenomena

This section presents the properties of the identified communication phenomena with regards to their various parameters described earlier. It is not the aim of this presentation to provide a thorough presentation of the phenomena, but merely to describe the basic properties in order to outline the landscape of electronic information and communication.

Below, the various matrixes are presented. The content of the cells (i.e. the properties attributed the various communication phenomena) are based on the author's conception and is in no way results of empirical studies. Nor are they accompanied by any form of justification of the choices. However, the way the cells are filled out is in accordance with common consensus and hardly the case of any debate.

In order to avoid confusion and misunderstanding, the illustrative matrix below explains the placement of the terms presented

| Dimension (for example interactivity) | | |
|---|--|---|
| Sector/Phenomenon | Parameter (for example Person Interactivity) | Parameter (for example machine interactivity) |
| Sector (for example television) | | |
| Phenomenon (for example television) | Property (for example none) | Property (for example low) |
| Phenomenon | Etc. | Etc. |
| Etc, etc. | Etc. | Etc. |
| Sector (for example telephony) | | |
| Phenomenon (for example POTS) | Etc. | Etc. |
| Etc, etc. | Etc. | Etc. |

Figure 20: The placement of terms in matrixes.

The reason for presenting separate matrixes for each dimension each containing a number of parameters is the sheer size of the total matrix. The number of columns and rows would exceed normal levels of intuitive comprehension.

6.4.1. Appliances

| Appliances | |
|------------------------------|------------------|
| Sector/Phenomenon | Appliance |
| Television/mass media | |
| Television | TV set |
| Teletext | TV set |
| Radio | Radio |
| Telephony | |
| POTS | Telephone |
| Mobile telephony | Mobile phone |
| SMS | Mobile phone |
| WAP | Mobile WAP Phone |
| Telefax | Fax machine |
| Computers/Networking | |
| WWW (web pages) | Computer |
| Email | Computer |
| Newsgroups | Computer |
| Chat | Computer |
| Games/business applications | Computer |
| IP-telephony | Computer |
| Webcam | Computer |
| P2P | Computer |

Table 3: The appliances dimension, its parameters and properties.

As can be observed in the table above, the television and telephony sector to a large extent make use of dedicated appliances, where the computers/networking sector is based upon one single apparatus (however with the possibility increasing flexibility of replacing/adding certain components inside the computer).

The appliances of the television and computer/networking sectors are subject to thorough investigation in the case study of television computers or TVPCs.

6.4.2. Interactivity

| Interactivity | | |
|------------------------------|-----------------------------|--|
| Sector/Phenomenon | Person Interactivity | Machine Interactivity |
| Television/mass media | | |
| Television | None | Low (selection) |
| Teletext | None | Carrousel |
| Radio | None | Low (selection) |
| Telephony | | |
| POTS | High | High when connecting, low when communicating |
| Mobile telephony | High | High when connecting, low when communicating |
| SMS | High | High |
| WAP | High | High |
| Telefax | High | Medium |
| Computers/Networking | | |
| WWW (web pages) | None | High |
| Email | High | Medium |
| Newsgroups | High | Medium |
| Chat | High | High |
| Games/business applications | None | Very high |
| IP-telephony | High | Medium |
| Webcam | None/low | Low |
| P2P | Low | Medium |

Table 4: The interactivity dimension, its parameters and properties.

The table shows a noticeably low level of interactivity – person as well as machine – in the television/mass media sector compared to the other two sectors. This observation is put in relation to other observed properties later in this chapter.

6.4.3. User Interface

| User Interface | | |
|------------------------------|--------------------------------------|---|
| Sector/Phenomenon | Control capabilities | Modality |
| Television/mass media | | |
| Television | Remote control | Video, Sound (stereo), Text |
| Teletext | Remote control | Text, primitive graphics |
| Radio | Buttons on appliance, remote control | Sound (stereo) |
| Telephony | | |
| POTS | Dial or buttons | Sound (mono) |
| Mobile telephony | Buttons | Sound (mono) |
| SMS | Buttons/keyboard | Text |
| WAP | Buttons/keyboard | Text, primitive graphics |
| Telefax | Buttons/keyboard | Text, graphics |
| Computers/Networking | | |
| WWW (web pages) | Mouse, keyboard | Text, graphics, images, moving pictures, sound |
| Email | Keyboard | Text, tags |
| Newsgroups | Keyboard | Text, tags |
| Chat | Keyboard | Text, tags |
| Games/business applications | Mouse, keyboard, joystick | Text, graphics, images, moving pictures, 3D graphics (stereoscopic), sound (stereo) |
| IP-telephony | Webcam, Microphone, Mouse, Keyboard | Sound, video, graphics, text |
| Webcam | Mouse, Keyboard | Moving pictures, sound |
| P2P | Mouse, Keyboard | Text, Graphics |

Table 5: The UI dimension, its parameters and properties.

The control capabilities range from very simple (on-off button, channel selector and a few additional buttons on a radio) to very complex (keyboards, mice, joysticks, head tracking, speech recognition etc. on a computer). A wide array of sensitive control capabilities is however not the sole precondition for high interactivity - but obviously it opens a lot of possibilities for interaction.

Also on the modality - i.e. the output - side, the computers are clearly the most capable pieces of hardware, though the content - take for example a text email - often does not exploit the possibilities of the appliances. This particular aspect of modality and the potential of innovations within this area are being investigated in the “modality” case study.

6.4.4. Organisation

| Organisation of Communicating parties | | | | |
|--|--------------------------|-----------------------------|---------------------|---|
| Sector/Phenomenon | Number of linked sources | Communication Modes | Forum/Audience Size | Forum Symmetry |
| Television/mass media | | | | |
| Television | Few | One-to-many | Large | None |
| Teletext | Few | One-to-"not so many" | Large | None |
| Radio | Few | One-to-many | Large | None |
| Telephony | | | | |
| POTS | One | One-to-one | Small | Total |
| Mobile telephony | One | One-to-one | Small | Total |
| SMS | One/few | One-to-one | Small | Total |
| WAP | Many | One-to-many | Small | Small |
| Telefax | One | One-to-one | Small | None |
| Computers/Networking | | | | |
| WWW (web pages) | Many | One-to-many | Large | None |
| Email | One | One-to-one | Small | Total |
| Newsgroups | Many | Many-to-many | Large | Large (can be moderated) |
| Chat | Few | Many-to-many | Medium | Total |
| Games/business applications | None | One alone | Small | None |
| IP-telephony | Few | Few-to-few | Small | Total |
| Webcam | None | One-to-many | Large | None |
| P2P | Many | Many-to-Many or Many-to-one | Large | Large (though users are rated) (total for Gnutella) |

Table 6: The organisation dimension, its parameters and properties.

Without going into too much detail, the matrix above indicates that the television sector - as opposed to the telephony and computer/networking sectors - has clear mass medium properties. This is of course also true to some computer phenomena - especially the web, which on the other hand indicates a larger versatility of this sector

6.4.5. Transmission

| Transmission | | |
|------------------------------|---------------|--------------------|
| Sector/Phenomenon | Casting Scope | Switching, Routing |
| Television/mass media | | |
| Television | Broad | None |
| Teletext | Broad | None |
| Radio | Broad | None |
| Telephony | | |
| POTS | Uni | Circuit |
| Mobile telephony | Uni | Circuit |
| SMS | Uni | Circuit |
| WAP | Uni | Packet |
| Telefax | Uni | Circuit |
| Computers/Networking | | |
| WWW (web pages) | Uni/multi | Packet |
| Email | Uni/multi | Packet |
| Newsgroups | Uni/multi | Packet |
| Chat | Uni/multi | Packet |
| Games/business applications | None | None |
| IP-telephony | Uni/multi | Packet |
| Webcam | Uni/multi | Packet |
| P2P | Uni | Packet |

Table 7: The transmission dimension, its parameters and properties.

Considering the somewhat trivial fact, that a transmission system capable of delivering information to specific recipients also has the possibility of sending to all of them, the systems of the telephony and computers/networking systems clearly have the upper hand in terms of flexibility. There are, however, bandwidth issues that might keep this flexibility from being fully explored, as described in the “Hybrid Communication and Information Case Study”.

A highly topical discussion taking place now - by the turn of the millennium - concerns the possibility that digital television transmission systems currently under development and implementation might be overtaken - and even made obsolete - by the development of bandwidth in household Internet access. This scenario – and especially the opportunity of a successful symbiosis between the two systems – is also investigated in the Hybrid Communication and Information Case Study.

The necessary precondition for this shift would be that the transmission systems of the computer/networking sector - even though it would still have to reserve capacity for the specific routing²⁰³ - would surpass the capability of digital cable, terrestrial and satellite television distribution. The imagined scenario typically is the reduction of television operators into mere content providers delivering television programmes via the Internet. In order to properly analyse such a scenario, one would have to include the considerations in the organisation matrix presented earlier. Again, a clearer distinction between hardware and content in the taxonomy would be desirable.

6.4.6. Time

| Time | |
|------------------------------|-------------------------------------|
| Sector/Phenomenon | Immediacy or Temporal Synchronicity |
| Television/mass media | |
| Television | High |
| Teletext | Low |
| Radio | High |
| Telephony | |
| POTS | High |
| Mobile telephony | High |
| SMS | High |
| WAP | Medium |
| Telefax | Low |
| Computers/Networking | |
| WWW (web pages) | Low |
| Email | Medium |
| Newsgroups | Low |
| Chat | High |
| Games/business applications | High |
| IP-telephony | High |
| Webcam | High |
| P2P | Low (Queuing appears) |

Table 8: The time dimension, its parameters and properties.

²⁰³ The underlying assumption is, that a broadcast system *ceteris paribus* has a larger capacity than a system capable of routing a signal to the intended recipient. This difference in capacities would be due to a: time consumption of the routing process and b: a smaller and less capable network because of the larger complexity and therefore higher price of infrastructure.

The level of immediacy or temporal synchronicity seems equally spread over the three sectors.

One central precondition for the lack of immediacy (or put positively: the possibility of receiving a message at any time convenient) is the existence of a storage medium in which the information can reside until the recipient wants to receive it.

Examples of such media are mail servers (where the email resides until read) and a VCR (Video Cassette Recorder), on which the user can record a TV broadcast for later viewing at a convenient time. This latter phenomenon is known as “time shifting”.

6.4.7. Usage scenarios

| Opportunities and usage scenarios | | |
|--|--|----------|
| Sector/Phenomenon | Number of simultaneous users on one terminal | Mobility |
| Television/mass media | | |
| Television | Individual/group (family) | Low |
| Teletext | Individual | Low |
| Radio | Individual/group (family) | High |
| Telephony | | |
| POTS | Mostly individual | Low |
| Mobile telephony | Individual | High |
| SMS | Individual | High |
| WAP | Individual | High |
| Telefax | Individual | Low |
| Computers/Networking | | |
| WWW (web pages) | Individual | Low |
| Email | Individual | Low |
| Newsgroups | Individual | Low |
| Chat | Individual | Low |
| Games/business applications | Individual | Low |
| IP-telephony | Individual | Low |
| Webcam | Individual | Low |
| P2P | Individual | Low |

Table 9: The use dimension, its parameters and properties.

The table indicates a pattern of individual use and low mobility in the communication forms originating from the computer/networking sector, while the pictures in the other two sectors is somewhat less clear.

A highly topical convergence phenomenon in the field of mobile communication is the imminent battle between mobile telephones and telephony enabled palmtop computers (so called PDAs). Both of these products might be seen as developing from different points of departure, along different trajectories, but towards the same final product: a mobile multi purpose, multi-modal communication device.

Mobility considerations also recently (during the late 1990's) came into play in the planning of wireless digital television in several European countries. Here, it was of significant importance in the considerations between different wireless technologies, that terrestrial transmission has the particular benefit over satellite distributed digital television, that it can be received via a small antenna without the need for orientation that makes dish based satellite receivers inherently stationary.

6.5. Conclusion

This chapter has suggested a taxonomy for a number of electronic information and communication phenomena. Presumably, most of the phenomena relevant by the time of writing²⁰⁴ have been included in the taxonomy. New infocom phenomena will undoubtedly emerge in the coming years - making the present version of the taxonomy incomplete. However, the basic structure of the taxonomy makes it suitable for later inclusion of new phenomena. Also with regards to the properties presented, the taxonomy is quite flexible and able to tolerate alterations - for example in the case of identification of new relevant parameters in further research.

The taxonomy provides a useful framework for plotting and identification of existing and future communication phenomena. Using the taxonomy, new phenomena can be analysed in a context coherent with earlier research - and easily compared to related existing forms of communication.

6.6. A Layered Taxonomy Framework

During the work with the taxonomy of electronic information and communication, it has become obvious, that the taxonomy could benefit from a reduced complexity by having its parameters distributed onto a number of layers. This adds to the clearness of the taxonomy, and furthermore gives a more logical representation than when the parameters are bundled together under the different dimension headers.

The intention with this development of the taxonomy is also to leave out some of the dimensions and parameters, which are “leftovers” from the old-fashioned perspective

²⁰⁴ Being one of the early works of this PhD project, the taxonomy was formulated in March 2000 during an external research stay at Siemens in Milan.

of three sectors – or in other terms: to create a framework²⁰⁵ for a taxonomy of past, present and future forms of electronic information and communication, solely based on objective characteristics.

Thus, this section proposes a revised²⁰⁶ taxonomy with the parameters ordered according to three layers: content, infrastructure and appliances. Hereby, the hierarchical order of dimensions containing one or more parameters is abandoned. The parameters are now ordered in the three layers instead. The distribution onto these three layers strongly supports the trend in this whole dissertation: the perspective of appliances, infrastructures and content as the main focus areas of convergence.

The logic behind sorting the parameters in layers (as opposed to e.g. keeping them in separate boxes without specifying any particular order) is the way that the information consumption or communication process takes place: content is distributed via infrastructures and consumed on appliances. This layered approach also allows for later expansion of the framework with other layers – depending upon the task at hand. E.g. a legal or regulatory layer could be applied if these issues are in focus. The term “layer” gives associations to the OSI model²⁰⁷. As such, the revised taxonomy can be seen as a result of the – for the purpose of this PhD-project – unnecessary technical detail of the OSI model as described in the Theory chapter on page 92. An alternative to the notion of “layers” could have been “links” – hereby giving the taxonomy some resemblance to the value chain model of Michael Porter²⁰⁸, but this would imply a more business related perspective of the taxonomy than is the intention.

6.6.1. The taxonomy framework

The actual information and communication phenomena are left out of this version of the taxonomy, which thus serves as a framework for taxonomies rather than a taxonomy as such. The usability of the taxonomy is that any form of electronic information consumption or communication can be mapped in this framework according to its characteristics in each of the three layers.

The “Appliances” dimension and its matching “appliances” parameter²⁰⁹ is left out, which is in accordance with the basic idea of this project, that the boundaries between the traditional sectors are becoming blurred (and perhaps even disappearing).

²⁰⁵ The reason that this revision of the taxonomy is referred to as a “framework for at taxonomy” is the fact, that it does not contain a mapping of actual information and communication phenomena – a feature it should have had, were it to be a true taxonomy by itself.

²⁰⁶ This revised taxonomy has been developed in early 2003 - after the bulk of the PhD-project - and as such reflects a refined perspective bases on the experience gained during the project.

²⁰⁷ The OSI model is presented on page 5

²⁰⁸ Porter, 1985.

²⁰⁹ - as there is only this one parameter under the “appliances” dimension

Therefore, a suitable taxonomy of electronic information and communication should be void of such obsolete terms, and be open towards new phenomena.

Another dimension, which is left out, is that of “usage scenarios”, as it also suggests a particular usage of an information and communication phenomenon. Such a usage should not be “suggested” by a neutral taxonomy. If, e.g. a larger group of spectators wish to watch one user playing computer games, this should not be indicated by the taxonomy as not being an option. Furthermore, the usage scenarios are often given by the nature of content, as content with a broad scope of interest naturally would be consumed by groups. Other parameters as well, such as the user control capability, the modality and the communication modes lead to particular natural usage scenarios.

The Forum/Audience size has been left out of this revised taxonomy. This is due to considerations similar to those, that have lead to the exclusion of the “usage scenarios” dimension: As the taxonomy aims at being concerned only with objective characteristics, it should not suggest how big an audience would be interested in a particular piece of content.

The revised taxonomy framework contains of a three layer model with the parameters of the earlier taxonomy sorted as follows:

Appliances:

- Machine Interactivity
- Control Capabilities
- Modal Capabilities²¹⁰

Infrastructure:

- Casting scope
- Transmission²¹¹
- Number of linked sources
- Communication modes

²¹⁰ - one half of the earlier “modality” parameter.

²¹¹ Earlier referred to as Switching/routing. The new term “transmission” is chosen, as it is more neutral and allows for future forms of transmission to be included. It also accommodates the transmission form of traditional television, which most appropriately can be defined as “constantly switched”.

Content:

- Person Interactivity
- Modal Properties²¹²
- Forum Symmetry
- Immediacy²¹³

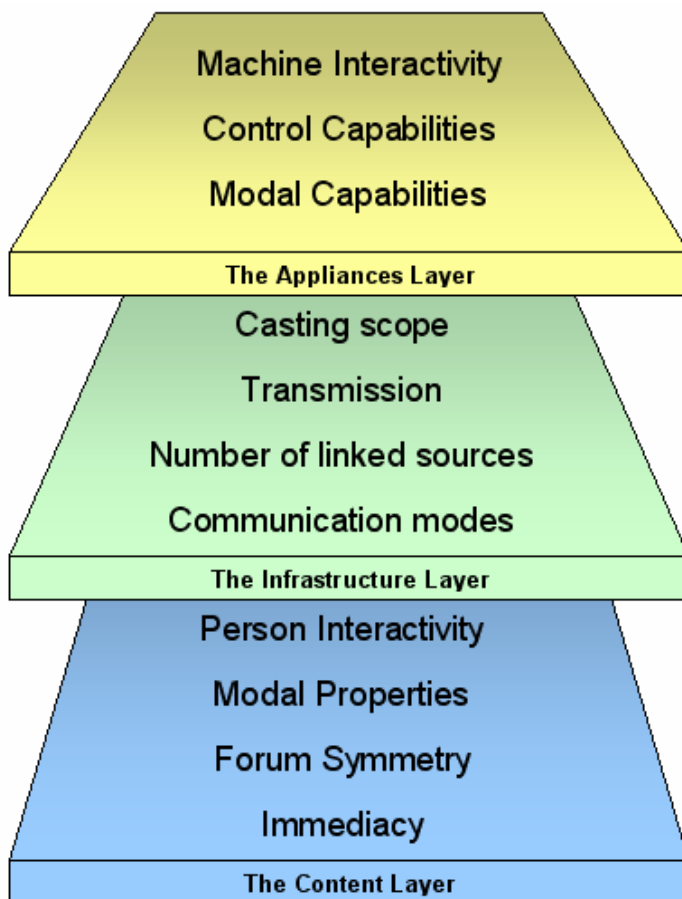


Figure 21: Framework for a taxonomy of electronic information and communication.

²¹² - the other half of the earlier "modality" parameter

²¹³ The original term: "Immediacy or temporal synchronicity" has been shortened for simplicity – and to avoid redundancy.

The placement of some of the parameters within the various layers deserve additional explanation:

The earliermodality parameter figures in the appliance layer as “Modal Capabilities” (because appliances can have varying presentation capabilities) as well as the content layer as Modal Properties (because the content can contain particular modalities).

“Communication Modes” is placed in the Infrastructure layer, because the modes (whether the communication is one-to-one, many-to-many, etc), primarily depend on whether the contact between these communicating parties are allowed by the infrastructure.

“Forum Symmetry” is placed in the Content layer. Here, it represents the symmetry, which is implied by the content’s properties (e.g. a football match requires no feedback from spectators – apart from cheering, booing and throwing bottles - and thus is an inherently asymmetric form of content). The “infrastructural” sibling of this parameter is the “Communication Modes” parameter, which describes the forms of contact made possible by the infrastructure.

“Casting Scope” and “Number of Linked Sources” both figure in the Infrastructure layer. Though they cover similar topics, they are indeed different: Casting Scope describes the number of recipients of a particular type of content (one, if it is unicasting; many, if it is broadcasting). Number of linked sources, on the other hand, describes the number of sources of content available to the user, thus representing the alternate direction, seen from the information consumer’s point of view.

The framework presented above contain the parameters necessary to describe past, current and – perhaps most importantly – future electronic information and communication phenomena. Any phenomenon can be mapped in the framework according to its content it offers, the infrastructure it utilizes and appliance on which it is consumed.

The taxonomy framework is limited to the focus area of this PhD-project. Within this focus, it covers the important aspects. Outside of this focus – e.g. for a business, legal or societal analysis, the appropriate layers can be applied to the existing three, making this framework a versatile starting point.

7. Signal, Interconnection and Content Standards

Many other factors than the purely technical ones influence the convergence between television and computer/networking. Also social and economic forces are at play, and have strong influence on the future forms of electronic information and communication. These factors manifest themselves – among other places – in the standardization processes and standards that characterize the landscape of convergence today. These standardization processes are not merely determined by technical considerations. Societal and economic interests play important parts as well.

The societal interests are often (within a standardization perspective) seen as manifested in the regulatory standardization – the so-called “de jure” standardization. The economic interests (those of firms and consortia), in turn, are most obvious in the alternative – “de facto” form of standardization. This does, however, by no means indicate a strong separation of societal and economic interests onto de facto respectively de jure standardization traditions. Many of the legislative choices in de jure standardization are directed not only by considerations such as the benefits of citizens, but also by interests based on political economy and national or regional prosperity. Correspondingly, the de facto, market-driven standardization is not solely an economic matter. Also here, aspects such as the appropriateness of having market selection determining the standards are important.

An important issue in the convergence between computers and television are the differences that can be observed between the sectors of television and computer/networking - not only in the standards themselves, but also in the standardization processes and traditions leading to them. It is fair to say, that convergence is not only taking place between content, infrastructure and appliances, but also in standardization traditions. This chapter, supplemented with the “New Standardisation Fora and Their Relationships with Traditional Standardisation Organisations” paper in the appendix (pages 309ff), goes into considerable depth in describing the technical aspects of the standards most relevant to the convergence process, but also accounts for the economic and societal processes behind the development and implementation of the most important of the standards of television and computer/networking.

The chapter provides an overview of important standards in television and computer/networking, and examines the current ongoing process of digitalisation and convergence. Hereby, it identifies a number of standardisation related drivers of - and obstacles to - the convergence between television and computer/networking. Furthermore, the influence of standards and technologies upon the innovation potential of the various sectors is described. The main focus is on convergence between TV and computer/networking, and the perspective is mainly – but not exclusively - that of the end user.

Building upon the earlier identified three major issues in convergence: *Interoperability, Interactivity and Quality* mentioned on page 3 ff, the investigation and analysis of this chapter provides the basis of the three case studies:

- The TVPC Case Study
- The Modality Case Study
- The Hybrid Communication and Information Case Study

The focus is first and foremost on an identification of the important audio and video standards in television and computer/networking, but the standards for interconnection of appliances and the storage of content are also taken into consideration. The issue of access to content is also described, and the chapter touches upon the interplay between hardware innovations and the supply of corresponding content.

Parts of this chapter is based on a paper²¹⁴ for a Ph.D. course, describing the research area and focus issues of this project. It is adjusted for the use within this dissertation, and a number of corrections and additions have been done.

The convergence in focus here is the type that appears, when appliances of one sector are used for forms of communication or information consumption characteristic of another sector. When attempting to communicate or consume information on an alternative appliance or via an alternative network, the user often encounters problems related to standards. Standards from different sectors often lack mutual *interoperability* and *compatibility*.

An example: If the user wants to view the picture coming from his or her computer on the television set, a number of difficulties have to be overcome. The most important is the video signal conversion: Today's household computers have a VGA interface between the monitor and the computer itself. Unfortunately, the common television set does not accept this kind of signal. Hence, conversion of the signal is necessary, and can be obtained via either an external conversion box or a dedicated graphics card delivering s-video or composite signal from the computer.

Example box 2: A technical barrier to convergence.

In the present situation, we have a number of standards specifying both the *appliances* and the *content* that is consumed on them. The standardisation of appliances can furthermore be divided into two main categories: *signal standards* and *interconnection*

²¹⁴ Oest, 2001.

standards. There is a certain overlap between these categories: a certain signal standard is often related to a certain interconnection standard – for example S-Video with its separate chrominance and luminance uses a dedicated 4-connector S-Video Cable. The separation between signal and interconnection standards is maintained nevertheless, as examples of the same type of signals running over different interconnection standards exist (for example composite video running over a coaxial cable OR over a Euroconnector (Also known as a SCART connector)) .

7.1.1. Modality and quality

The term modality covers the sensory input received by the users in a communication or information consumption process. Traditionally, these inputs have been limited to sound and vision. In a traditional telephone conversation, mono sound is – and has always been - the primary mode of communication. In the television sector, sound and moving pictures have since the 1930's been the content received by viewers. In contrast to the telephony sector, there has been some development both in modality and quality, though. Picture resolution has improved over the years, colour has been added, and on the audio side, stereo sound has increased the credibility of the programs.

By contrast, the computer was originally designed to display graphics. During the 1990's computers have developed into multi-modal pieces of hardware giving the user stereoscopic colour vision and surround sound. In addition, force-feedback devices have added a further tactile modality to the process²¹⁵.

It seems that the flexibility of the computer allows it to work with a wide array of innovations. As opposed to television sets and telephones, the computer isn't designed for use with one particular source. This relates to the flexibility-related research questions of this thesis, concerning the question of whether development and innovation take place at a much faster rate in the computer sector, because computers have the flexibility to adopt new communication methods.

7.2. Signal Standards

When a video or audio signal is transmitted – be it over large distances or between appliances – there are a number of standards commonly used for defining the properties of the signal in question. As the television sector and the computer/networking sector have until recently been disjunctive, a number of standards have emerged and established themselves within each sector. Now - with the convergence between sectors taking place, the benefit of mixing the content and

²¹⁵ The author has done a number of experiments with these possibilities under the MultiModality case study.

appliances of these two hitherto separate sectors becomes obvious. These possibilities are further explored in the “Hybrid Communication” case study.

Signal: *the sound or image conveyed in telegraphy, telephony, radio, radar, or television.*

Definition 27: Signal (a lexical definition)²¹⁶.

One of the main differences among the converging sectors has to do with the nature of the signals. Traditionally, the telephony and television sectors have used analogue technology. Lately, a switch to digital transmission in these sectors can be observed. This should not be seen solely as a result of the convergence process – the switch to digital telephony, for example, started long before computer networks in general and the Internet in particular became household terms²¹⁷.

Computers and computer networks are by contrast inherently digital. The digitalisation of television and telephony – be it as a result of convergence or merely inspiration from the computer/networking sector – will ease the cross-sector convergence by eliminating much D/A and A/D²¹⁸ conversion.

7.2.1. Video standards in the Television and Computer/Networking Sector

The convergence between television and computer/networking manifests itself in – among other areas – the viewing of content for one sector on the appliances originally belonging in another sector. This is a development that holds great promises, but especially in the areas of resolution and frame rate, there are a number of obstacles to the smooth transition of content from one sector to another. Interoperability of different resolutions and frame rates is not trivial. Scaling an image from e.g. 720x576 to 800x600 usually implies a decrease in picture quality.

From a consumer’s point of view, having a multitude of closely ranging resolutions to choose from is not attractive. Of course, being able to choose between different qualities of resolution and refresh rate when buying TVs, monitors and DVDs is a benefit, but being able to choose between e.g. a PAL television offering 625 lines and a NTSC television offering 525 lines is utterly uninteresting. What the consumer can hope for is the forming of a number of formats giving sufficient choice, but reducing the amount of confusion and interoperability problems.

²¹⁶ Merriam-Webster

²¹⁷ It is fair to say, that the big boom in awareness of the internet took place around 1995 – Authors own experience, no particular source. GSM, which is a digital mobile telephony system started in the early 1990s.

²¹⁸ Digital/Analog and vice versa.

At present, there are a number of established standards in the television sector as well as in the computer/networking sector. Whether any standard or group of standard will eventually win is not the issue here, but in order to describe and analyse the potential of the converging sectors, it is necessary to know the standards and related interoperability issues.

7.2.1.1. The Television Sector

The display device of a television set is traditionally a CRT (Cathode Ray Tube). This is still by far the most common form of television. For over a decade, projection TVs have existed, and by the turn of the millennium, large flat plasma displays have become available – though at a cost which for most buyers is prohibitive.

The CRT had been the preferred display device since the introduction of television in the 1930s. Apart from the addition of colour in the fifties and sixties, the CRT has remained largely unchanged. With High Definition Television (HDTV) development of more advanced displays has been stimulated.

Scan method

Until the arrival of HDTV, all television signals were broadcast as *interlaced* video. Hence, all TV sets used interlaced scan – meaning that first, every odd scanline was drawn, then every even scanline (instead of progressive scan, meaning that the lines are simply drawn from the beginning to the end). The method of interlaced scanning is a heritage from the early days of television, where it was impossible to manufacture sufficiently fast-scanning cathode ray tubes. In the households, there is an immense installed base of television sets. Therefore, there is much reluctance among broadcasters, movie companies and other actors to introduce progressive scan units.

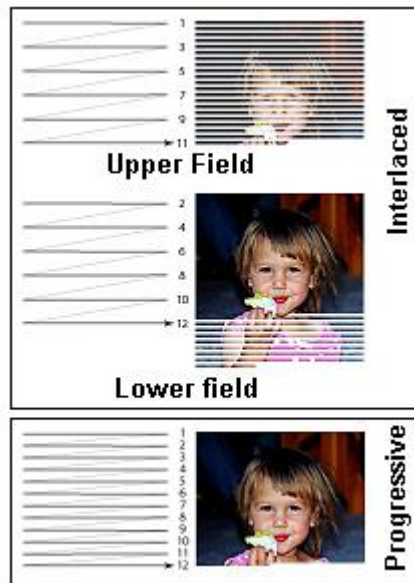


Figure 22: Interlaced and progressive scan methods²¹⁹

Interlaced scan takes place at double the rate of progressive scan at the same resolution, hereby minimizing flicker at low refresh rates (meaning that e.g. 25 Hz progressive scan equals 50 Hz interlaced. One could also say that 25 progressive *frames* per second equals 50 interlaced *fields* (which is 25 interlaced frames) per second. When the refresh rate capabilities of displays are sufficiently high, there is no reason for using interlaced scan.

Resolution and Scan Rate

As for the issue of interlaced or progressive scan, the HDTV standard leaves room for both methods. Furthermore, a variety of resolutions and refresh rates are included in the standard, leaving room for six different HDTV standards:

²¹⁹ Images are from: Adobe Premiere Technical Guides: "Interlaced and non-interlaced video" (online reference: www.adobe.com/support/techguides/premiere/prmr_interlace/prmr_interlace.pdf – link active per 020530)

| Resolution | Frames per Second ²²⁰ | Scan method |
|------------|----------------------------------|-----------------|
| 1280x720 | 24, 30 and 60 | p (Progressive) |
| 1920x1080 | 24 and 30 | p |
| 1920x1080 | 30 (60 fields per second) | i (Interlaced) |

Table 10: The North American HDTV standards²²¹

Among these formats, American broadcasters have settled on three combinations: 480p, 720p, and 1080i, where the number indicates the number of lines, and the letter the scan method. Among these, 480p is not regarded as HDTV, but it is nevertheless part of the ATSC specification for digital television. The competition between the two other formats, 720p and 1080i is not settled yet. Some broadcasters – e.g. CBS and NBC – use 1080i, while others – such as ABC – prefer 720p, and it is unclear, which – if any – of the format will prevail. Though TV tuners in the US are required to be able to decode all ATSC formats²²² (18 in total), one can expect a standards battle on this issue, as a number of factors (exchange of programs between broadcasters, encoding hardware etc.) will point towards the benefit of one common standard. There is a risk, that the television sector sticks with the interlaced formats, hereby hampering convergence, but on the other hand also risking losing market shares – especially those costumers which are concerned with high image quality - to the computer/networking sector.

There is hardly doubt, that – given the capabilities of today's display devices – interlaced scanning is the (at least technically and quality wise) better method of the two. This is even supported by the Advanced Television Systems Committee (ATSC) – which is the standardisation authority defining the North American HDTV standard. In a document they state that: *“It is well understood that format conversions involving interlaced scan formats require careful attention to de-interlacing, while progressive scan formats offer fewer conversion challenges.”*²²³

Hence, if the interlaced scanning method prevails in the HDTV and DVB markets, it is possible that we have a case of *third degree path dependence*. This possibility is further elaborated upon in the conclusions of the TVPC case study on page 198.

²²⁰For interlaced scan, the number of *fields* per second is twice the number of *frames* per second.

²²¹Federal Communications Commission ", 1995, p.13.

²²²Silva, 2002.

²²³Advanced Television Systems Committee, 1998, p.8.

"...after more than five decades of using the interlaced format for production and transmission, broadcasters have become accustomed to it. They also have substantial investments in the equipment that supports it."

Quote box 6: The broadcasters reluctance towards progressive scan²²⁴.

Another major player, the movie industry, has already demonstrated its desire to block interoperability with the regional coding of DVDs, making it difficult to play a North American DVD on a European DVD player. They too could have an incentive to stick to interlaced scan, hereby reducing their content's usability on computers²²⁵, which are subject to more global standardisation²²⁶ than the television sector appliances.

Standardisation processes

There has been – and is – a simultaneous development of digital television systems worldwide. Three major areas – the U.S. Europe and Japan have each their own trajectories of development. Among these, the main effort is on describing the U.S. and European development. The European, because this is the main focus of this thesis, and the U.S., because much of the content consumed on TV sets in Europe is produced here, meaning that conformity with the U.S. standard is desirable, as it eases the viewing of U.S. TV programmes in Europe.

²²⁴ Eisenberg, 1998.

²²⁵ Usability of interlaced content is reduced on a computer, because conversion to progressive scan is necessary. This conversion is certainly possible, but with some reduction in quality.

²²⁶ Circumvention of regional DVD codes is considerably easier on a computer, where only software modifications are necessary. On stand-alone DVD players, soldering is needed to bypass the region code counter. Therefore, it is likely that the movie industry wants their content to be consumed on traditional television sector appliances, the development of which they can more easily influence.

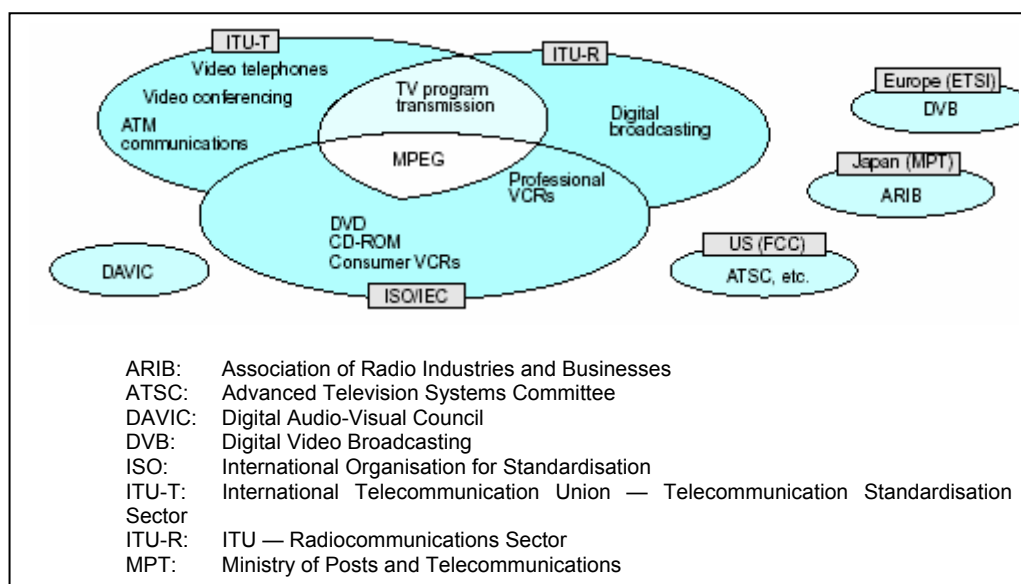


Figure 23: Digital broadcasting standardisation organisations²²⁷.

Compared to Europe, the specification and development of U.S. digital television is further. The specification for the United States was carried out by the Advanced Television Systems Committee, Inc. (ATSC) on behalf of the US Federal Communications Commission. The ATSC was originally a pure NSO (National Standardisation Organisation), but has expanded its focus to also include Mexico and Canada, effectively becoming an RSO (Regional Standardisation Organisation), as it expects the ATSC HDTV specification to become the North American standard²²⁸. The interests and desires of a number of consortia and other players have influenced the work.

The ATSC HDTV standard was in place by 1996, following a battle between two major alliances over a number of important details. The two combatants were the so-called “Grand Alliance” consisting of players belonging in the television sector²²⁹, and CICATS²³⁰, a coalition representing players from the computer industry. Both wanted to influence the coming HDTV standard – mainly focusing on two issues:

²²⁷ Murakami, Tokumichi et.al., 1998, p.5.

²²⁸ ATSC: “Development of the ATSC Digital Television Standard”.

²²⁹ AT&T, General Instrument, MIT, Philips, The David Sarnoff Research Center, Thomson Consumer Electronics and Zenith.

²³⁰ Computer Industry Coalition on Advanced Television Service – per 1996 consisting of Apple, Compaq, Dell, Intel and Microsoft.

- Interlaced vs. progressive scan
- Square vs. rectangular (or “non-square” pixels).

The positions of the two coalitions was rather predictable: The Grand alliance wanted the possibility of interlaced scanning methods and the use of rectangular pixels – phenomena known from the traditional television sector. CICATS, on the other hand argued, that technical quality would be improved by choosing progressive scan and square pixels – features already known from the computer world.

With the so called “Grand Compromise”, the FCC adopted a HDTV standard in 1996, which did not specify image formats, leaving it for the marketplace to decide, whether square or rectangular pixels would prevail²³¹.

To summarize the development of the three major digital television systems, a number of important parameters can be compared. The table below presents all the parameters specified by the standards, not only the ones that are actually used.

²³¹ McKinney, 2000.

| | Europe (DVB) | US (ATSC) | Japan |
|--------------------------------|--|--|---|
| Baseband signal ²³² | 576i: 25f/s (4:3 & 16:9) 1152i, 1080i/p: 25 f/s (16:9 & 2.21:1) 720p, 576p: 25, 50f/s(16:9 & 2.21: 1 or 4:3) and others (for 60Hz countries: 1080i/p: 30f/s, 1080p: 24f/s, 720p: 24, 30, 60f/s, 480i: 30f/s, 480p: 24,30,60f/s and others) | 1080i: 30f/s 1080p: 24 or 30f/s 720p: 24, 30 or 60f/s 480p: 24, 30 or 60f/s 480i: 30f/s and others (picture format) | 1080i: 1920 or 1440 pixels x 1080 lines, 30f/s 480i: 720 pixels x 480 lines, 30f/s 480p: 720 pixels x 480 lines, 60f/s 720p: 1280 pixels x 720 lines, 60f/s verification required) 1080p: 1920 or 1440 pixels x 1080 lines, 60f/s (under study) |
| Source coding (video, audio) | MPEG-2 video, MPEG-2 audio, Dolby Digital (aka AC-3) ²³³ | MPEG-2 video, Dolby AC-3 | MPEG-2 video, MPEG-2 AAC |
| Multiplexing | MPEG-2 transport stream | MPEG-2 transport stream | MPEG-2 transport stream |
| Application | Satellite Terrestrial Cable | Terrestrial | Satellite Terrestrial Cable |

Table 11: Important parameters in the major three digital television standards²³⁴.

It is important to note, that while the European DVB standard and the Japanese standard contains sub-standards for satellite, terrestrial and cable, the U.S. standard is primarily a terrestrial one.

The European Development

In Europe, the development in television resolution has not developed to the extent that it has in the U.S. A digital video broadcast system, DVB, has been developed by a consortium consisting of broadcasters, manufacturers, network operators, software developers and regulatory bodies²³⁵. The overall standard development is handled by a joint technical committee (JTC) with participation from European Telecommunications Standards (ETSI), the Centre for Electrotechnical Standards (CENELEC) and the European Broadcasting Union (EBU)²³⁶.

²³² Please note that this table lists the active lines in a TV picture, a number which is lower than the actual number of lines used elsewhere. A PAL signal, e.g., has 625 actual lines, however only 576 are used for the picture. For NTSC the corresponding figures are 525 and 480.

²³³ DVB support for Dolby Digital (aka AC-3) was not mentioned in the original source of the table.

²³⁴ Murakami, Tokumichi et.al., 1998, p.4.

²³⁵ The Digital Video Broadcasting Project.

²³⁶ DVB – Standards and Specifications.

Resembling the North American HDTV development, DVB is developed not purely by a consortium, but on the other hand, not purely by a regional standards organisation (RSOs). As the American standard, it supports a wide variety of resolutions, but unlike in the U.S., the high resolutions have not yet been implemented in Europe. The DVB broadcasts are in 625 lines, 50 Hz interlaced (i.e. 25 frames or 50 fields per second), hereby viewable on traditional PAL and SECAM television sets, and simulcast of higher resolution programmes will not appear until sufficient consumer demand makes it relevant²³⁷. European Broadcasting Union's (EBU) Head of New Technology, David Wood, has explained²³⁸:

"...none of the programme service providers see a viable business plan in HDTV, bearing in mind the cost and availability of HDTV receivers, and the cost of HDTV programme production..."

He further adds:

"...it is widely recognised that the future of television will be HDTV, and we wait and watch what happens in the United States and Australia with their HDTV broadcasts."

Here, the effects of the installed base of PAL and SECAM TV sets in European homes is easily recognizable: In order for broadcasters to see a profit opportunity in HDTV, there must be a sufficient number of users who are able to watch the programmes.

The differences between U.S.A. and Europe in the speed of development in digital and high-definition television can to a great extent be explained by the differences in standardisation process. In the U.S., the Federal Communications Commission (FCC), which is a national standardisation organisation, has had powerful control of the development process. By contrast, the RSOs of Europe have less formal power and are further hampered by the need for agreement between its very different member states (for example, in Europe, there are two analogue TV standards: PAL, used by most of Europe, and SECAM, mainly used by France).

²³⁷ Mitianoudis, p.2.

²³⁸ Jacklin, Martin et.al., 1998, p.4f.

This scenario calls for another angle of attack on the standardisation problem, as described by the European Broadcasting Union²³⁹:

Question:

... Why on Earth does not Europe – the EBU, even – follow the US and set about imposing an all-digital HDTV standard on broadcasters, industry and viewers alike?

Answer:

...The EBU, as a voluntary association of broadcasters, has no executive rôle to play in broadcast regulation. It works by recommendation, by gentle persuasion and, above all, by promoting the consensus views of its Members. The European Commission, for its part, seeks to lead its 12 Member-states by Directive – and the rest of Europe by example. In other words, neither the Commission nor the EBU is, or probably could be – or, indeed, would ever want to be – a European equivalent to the FCC.

The obstacles to HDTV in Europe is not in the DVB standard itself. In many ways, it resembles the North American HDTV standard in the fact that it uses MPEG2 for image and allows MPEG multichannel as well as Dolby Digital audio. It also supports both progressive and interlaced scan, 16:9 aspect ratio, resolutions up to 1920x1080 and up to 60 fps frame rate²⁴⁰. The many details the two digital televisions standards has in common makes it likely, that the European market will – once broadcasters see incentive to deliver HDTV content – use the same TV sets as the American market. With Europe lagging behind the U.S., one can expect that the price of TV sets for the U.S. market will have dropped to a level that makes it obvious to use them in Europe rather than trying to persuade TV manufacturers to produce sets for two standards – as is the case with NTSC, PAL and SECAM TV sets.

DVB Aspect Ratio

While being suited for 16:9 aspect ratio, DVB is not the first attempt to introduce this in Europe. During the 1990s, several European broadcasters have used the PALPlus format for widescreen programmes that can also be viewed on most newer 4:3 TV sets. The transition is however progressing slowly. Not many viewers – only an estimated 12,7 per cent for Europe in general²⁴¹ - have purchased 16:9 TV sets, and consequently, incentive among broadcasters to use this format for all programmes –

²³⁹ Waters, 1992.

²⁴⁰ ETSI Secretariat, 1997, pp.17ff.

²⁴¹ Crantor, et.al., 2000, p.10.

thus speeding up the adoption process – is limited. This is a classic chicken and egg-problem in a situation of standards adoption – a problem that is made even worse by the fact that many TV stations broadcast 16:9 programs in letterbox format rather than anamorphic widescreen. This reduces the picture quality for owners of 16:9 TV sets, as part of the resolution is spent on transmitting the black bars, leaving it to the 16:9 TV set to cut them away and zoom in on the “real” picture²⁴².

The fundamentals of the problem lie in the rigidity of the television screen: to view a 16:9 broadcast on a 4:3 screen, one must accept either cutting off the edges of the picture (letterboxing), or having black bars fill the top and bottom of the picture, hereby significantly reducing the effective number of lines. With the already limited resolution of the TV set, the reduction of resolution leads to a very coarse picture. On a computer monitor, by contrast, there is ample resolution to allow for black bars and still maintain the original number of lines.

| Year | Event | Remarks |
|-----------------|---|---|
| 1936 | First black and white television broadcast made available in London | 240 lines, 25 fps, progressive* |
| 1941 | 525 lines standard established in the US* | |
| 1954 | 525 lines NTSC standard colour TV introduced in North America.* | 30 fps interlaced |
| 1961 | 625 lines SECAM colour standard developed in France.* | 25 fps interlaced |
| 1963 | 625 lines PAL colour standard developed in Germany.* | 25 fps interlaced |
| 1967 | PAL and SECAM colour TV introduced in Europe* | |
| 1996 | US ATSC digital HDTV standard | Many combinations of resolutions and frame rate. |
| 1997 | European DVB trial transmissions ²⁴³ | 625 lines, 25 fps interlaced |
| 2007 (expected) | All US NTSC broadcasts are to be displaced by HDTV | Decided by the US FCC (Federal Communications Commission) |

Table 12: Important events in innovation in image in the TV sector. All unmarked information is from²⁴⁴. All information marked * is from²⁴⁵.

²⁴² Another disadvantage of having a 16:9 TV set zoom in on a letterboxed signal appears when the programme is translated, displaying the dialogue in the viewer’s native language as text bars in the bottom of the screen. These bars disappear when the TV zooms, leaving the viewer to understand a programme in a foreign language.

²⁴³ Skouby, et.al., 1998 (Appendix 1).

²⁴⁴ McKinney, 2000.

²⁴⁵ Peters, 2002.

7.2.1.2. The Computer/networking Sector

As is the case with the display devices of the television sector, the most numerous computer monitors use a cathode ray tube to generate an image. Due to the development in laptop computers over the last decade, LCD (Liquid Crystal Display) and plasma monitors have been more commonplace with computers than in the television sector. An important difference, though, is that the display standards are worldwide. The computer sector does not have the regional differences of the television sector with its non-interoperable (or at least “difficultly interoperable”) NTSC, PAL and SECAM standards.

While the CRT television set accepts a very narrow range of resolutions and refresh rates, a computer CRT monitor is far more flexible, and can accept a wide range of formats. The most advanced CRT monitors can accept resolutions of more than 1600x1200 pixels and refresh rates above 150 Hz. From the early days of personal computers, a set of three-letter specifications defined the video output of graphics adapters, hence also setting standards of the capability of monitors.

The early computer graphics formats were aimed at displaying text rather than graphics, images and video. The resolution was low, and early monitors were in monochrome, meaning that they were able to display two colours only – e.g. black and green. As such they were inferior to the monitors of the television sectors, which – though referred to as “black and white”, actually were able to display a whole range of greyscale. Until well into the nineties, the scanning method could be either interlaced or progressive. Actually, in the early nineties, when purchasing a computer monitor, it was necessary to specify whether it should be an “interlaced” or a “non-interlaced” monitor.

In 1987, the VESA consortium (Video Electronic Standards Organisation) introduced the VGA (Video Graphics Array) standard offering a resolution of 640x480, which made computer monitors quite close to television sets resolution-wise. This was soon increased by the introduction of SVGA (Super-VGA) offering a resolution of 800x600, effectively overtaking the resolution of television sets. A further increase in resolution came with VESA’s XGA (Extended-VGA), after which the idea of giving three- or four letter names to resolution standards went out of fashion.

Another display device that is often used in conjunction with a computer is the projector. Old projectors used CRT technology similar to that of the monitors, but later, LCD and DLP (Digital Light Processing) types of projectors have led to reduced size and price. Usually, the projectors are fitted with connectors for computers as well as television sector appliances, and can as such be used for both types of infocom. Here, it is important to notice, that projectors (LCD as well as DLP) are not flexible in their resolution. The number of pixels is fixed. The projectors usually do have internal scalars, altering the incoming signal to their so-called native resolution,

but image quality suffers considerably, unless they are fed with their native resolution. A similar limitation exists concerning the issue of refresh rates. Here, most projectors accept only one refresh rate. As with the resolution, they are able to convert the refresh rate to their desired one, but again, image quality suffers.

| Year | Event | Remarks |
|------|---|--|
| 1981 | MDA (Monochrome Display Adapter) * | Monochrome, displays ASCII characters. |
| 1981 | CGA (Color Graphics Adapter), 640x200, 16 colours.* | Introduced by IBM |
| 1985 | EGA (Extended Graphics Adapter), 640x350, 16 colours* | |
| 1987 | VGA, 640x480, 256 colours. | Introduced by VESA* - first 4:3 aspect ratio format. |
| 1988 | MPEG-1 | open (ISO/IEC) standard. |
| 1990 | IBM introduces XGA-8514A Interlaced 1024x768 standard.* | |
| 1996 | MPEG-2 | open (ISO/IEC) standard. Used for HDTV and DVD. |
| 1999 | MPEG-4 ratified | open (ISO/IEC) standard. |
| 2002 | Consumer Graphics cards offer 2048x1536 ²⁴⁶ | |

Table 13: Important events in innovation in image in the computer/networking sector. All unmarked information is from²⁴⁷. All information marked * is from²⁴⁸

The MPEG series of standards figure in the table of computer/networking, but they actually belong to both sectors. Developed by the Moving Pictures Expert Group (MPEG), a committee of ISO/IEC, the MPEG series of standards have been adopted by both the television and the computer/networking sector. As such, it is an interesting convergence phenomenon, and has the potential of actually serving as a “driver” of further convergence.

The MPEG1 standard is used for encoding video files on computers, but also for Video CDs (VCDs), which can be played by most stand-alone DVD players, which must be regarded as a television sector appliance. MPEG2 standard is used for DVDs and digital television (again, primarily the television sector, but DVDs can also be played on computers with DVD drives and sufficient processing power). MPEG4 is primarily used in the computer/networking sector, where it has provided the basis for many more or less proprietary codecs – e.g. DivX and many of Microsoft’s .avi codecs.

²⁴⁶ This is true for a number of popular graphics card – see e.g.:

<http://www.asuscom.de/vga/agpv8460/specification.htm> (online reference - link active per 020530)

²⁴⁷ Online reference: <http://www.cvc.sunysb.edu/multi/courses/video.html> (link active per 020527).

²⁴⁸ Global Sources: “Audio and Video – Glossary of Terms”.

7.2.2. Audio standards in the Television and Computer/Networking Sector

As is the case with video standards, there are a number of different audio standards at play in both sectors. However, contrary to improvements in video format, the general perception of audio improvements have more to do with the number of channels than the deeply technical factors such as signal no noise ratio or frequency range.

One of the important types of innovations – and an easily measurable one – is the number of audio channels used for the content consumed on television sets or computers.

The fundamental advantage of having more sound channels is that it gives the listener a richer sound and a feeling of actually being present in the situations represented – be it a movie or a computer game. The generation of sound is done by traditional loudspeakers, which do not differ in any significant way across the sectors. The next link in the chain of equipment – the amplifier – is also quite similar, and Hi-Fi amps (which are regarded as belonging to the television sector) are quite capable of working with computers.

When looking at the way that the sound content is en- and decoded, a number of more fundamental differences become obvious. The differences in the nature of the content make for different approaches to multi channel sound design. While the content intended for the television sector is produced before being consumed, the sound information is already present, and efforts in development are focused on reducing bandwidth or storage space. The computer content that benefits from an increased number of sound channels are typically computer games and virtual reality presentations. Here, the sound is generated by the computer's soft- and hardware, depending on the actions of the computer's operator (typically the player). Hence, it is generated in *real time*, on the computer where the gaming or multimedia experience takes place. Bandwidth and storage become irrelevant considerations, while processing power and efficient software design become key priorities.

Here, we have two sectors, originally with different requirements for sound standards, but as the convergence process is progressing, more and more television content is viewed (and *listened*) on computers, as well as the television set increasingly becomes a communication – and especially a playing device. Thus, a meeting of the sound standards of these two formerly separate areas is taking place, accentuating interoperability and compatibility issues that until recently were non-existent.

7.2.2.1. The Television Sector

Over the last millennium, we have observed an increase in the number of audio channels put to use in order to give listeners a better listening quality or an increased

sense of presence. Early TV sets had a mono speaker only, built into the cabinet. For decades, this was the only available option. The quality of the images on television was increased considerably with the arrival of colour television, and the only obvious way to match this in terms of audio quality was by the use of two audio channels – a phenomenon known from the Hi-Fi world. Later increases in the number of audio channels followed, with a number of different approaches competing for domination.

The important events in the history of multi channel audio in the television sector (plus areas such as Hi-Fi and cinema) is as follows:

| Year | Event | Remarks |
|---------------------|---|--|
| 1958 | Two channel stereo LP | |
| 1961 | Two channel stereo FM | |
| 1972 | First quadraphonic albums issued ²⁴⁹ | |
| 1972 | Mono video cassette | |
| 1975 | German broadcasters invent "A2" stereo system for broadcast.* | |
| 1978 | Stereo video cassette | |
| 1980 | Stereo Laser Disc | |
| 1982 | Three channel Dolby Surround (left, right, center) | |
| 1982 | Two channel Compact Disc | |
| 1984 | The U.S. Federal Communications Commission (FCC) adopts BTSC (a.k.a. MTS) multichannel broadcast standard. ²⁵⁰ | |
| 1986 | NICAM stereo TV broadcast in the UK.* | Developed by BBC Research Centre |
| 1987 | Four Channel Dolby Surround Pro Logic (left, right, center, surround) | |
| 1993 | 5.1 channel Dolby Digital (AC3) chosen for ATSC digital TV | |
| 1993 | 5.1 channel DTS arrives ²⁵¹ | |
| 1994 | Sony's 7.1 channel SDDS system was launched in theatres ²⁵² . | No consumer version developed ²⁵³ . |
| 1995 ²⁵⁴ | Philips presents MPEG Multichannel for DVD and DVB. | |
| 1995 | 5.1 channel Dolby Digital on laserdisc | |
| 1995 | 5.1 channel Dolby Digital chosen for DVD | |
| 1998 | 5.1 channel Dolby Digital DTV broadcasting begins in the U.S. | |

Table 14: Important events in innovation in sound in the TV sector. All unmarked information is from²⁵⁵. All information marked * is from²⁵⁶.

²⁴⁹ Evans.

²⁵⁰ Easley.

²⁵¹ Eliasson, Leijon and Persson.

²⁵² Online reference: <http://www.sdds.com/scpc/index.html>. (link active per 020522)

²⁵³ Though SDDS (Sony Dynamic Digital Sound) figures as an optional DVD sound standard, Sony claims that no home cinema version of this system is developed: "Sony designed SDDS exclusively for motion pictures theatres. There is no consumer equivalent.", Sony Corp., online reference: <http://www.sdds.com/whatis/index.html> (link active per 020522)

²⁵⁴ No clear indication of the development of MPEG Multichannel could be found. An indication could however be observed from the remark: "...But when the SD and MMCD standard was merged into the DVD standard in late 1995, the DVD consortium decided to sell out PAL land to Philips MPEG2 multichannel audio..." (online reference: <http://home.online.no/~espen-b/mpeg/history.html> - link active per 020522)

The original sound formats – from mono over stereo and quadrasonic to Dolby Surround – were analogue formats. Dolby Pro Logic is the same as “plain” Dolby Surround apart from the fact, that it has a discrete centre channel.

The analogue surround information in Dolby Pro Logic is contained in the two stereo channels. To enjoy the surround effects in a TV broadcast, an external Dolby Pro



DOLBY SURROUND
PRO • LOGIC

Logic decoder is needed. Without the decoder, only the stereo sound is heard – the surround information does not influence it. With a decoder, the surround information is directed to the rear speakers, and the surround broadcasts of many TV stations can be enjoyed. There is wide agreement that this system does not come close to the digital surround systems in terms of quality, but given a TV system capable only of two analogue separate sound channels, it seems the best solution available.



In 1993, two important digital multi channel sound systems were introduced. Dolby Digital by Dolby Labs, and DTS by Digital Theater Systems, Inc. The difference between Dolby Digital and DTS are small. Main difference is that DTS is less compressed than Dolby Digital, and therefore takes up more storage space or bandwidth.



Originally, “Dolby Digital” denoted the cinema version, while “AC3” and “Dolby Surround 5.1” covered the home cinema market. The technical differences are however minor, and Dolby Labs recommend the term “Dolby Digital” as covering all three variants.

Whereas the specification of DVDs for the North American market (NTSC specification) seem to have progressed without much problems, the European market experienced a war on standards. Philips had developed the MPEG Multichannel standard for DVD sound and expected it to be mandatory for Europe.

²⁵⁵ Dolby Laboratories.

²⁵⁶ Hosgood, 1997.

| | NTSC Disc | PAL/SECAM Disc |
|-----------|---|--|
| Mandatory | <u>Either of the following:</u> Linear-PCM or Compressed Audio (AC-3) | <u>Either of the Following:</u> Linear-PCM or Compressed Audio - MPEG-1 layer II audio or - MPEG-2 layer II multi-channel audio which is backward compatible to MPEG-1 audio |
| Optional | <u>Any of the following:</u> - AC-3 (1 - 5.1 channel) - MPEG (1 - 7.1 channel) - DTS (1 - 5.1 channel) - SDDS (1 - 7.1 channel) - Others | <u>Any of the following:</u> - MPEG (1 - 7.1 channel) - AC-3 (1 - 5.1 channel) - DTS (1 - 5.1 channel) - SDDS (1 - 7.1 channel) - Others |

Table 15: Early Disc Specifications for Audio Coding for DVD-Video²⁵⁷

Due to a number of factors – among which the claimed inferiority to AC-3 and lack of decoder chips have been mentioned as important – the DVD forum (earlier known as the *DVD Consortium*) opted to change the specification of DVD audio.

In December 1997 the specification was changed to PAL/SECAM DVDs to include AC-3 instead of MPEG Multichannel as a mandatory option by the Steering Committee of the DVD Forum. The votes cast illustrate how the alliances in the DVD forum were formed: Hitachi, Matsushita, Mitsubishi, Pioneer, Thomson, Time Warner, Toshiba and JVC voted for the change, Philips and Sony against²⁵⁸.

AC-3 has become a competitor of MPEG Multichannel. According to the DVB Consortium, MPEG2 audio is recommended, but broadcasters are allowed to implement Dolby's AC-3 instead²⁵⁹. The DVB consortium claims that any difference in quality between MPEG and AC-3 is negligible, but still – probably forced by pressure from various players and interest groups - accepts the use of AC-3. It is

²⁵⁷ DVD Forum, 1997.

²⁵⁸ Braathen.

²⁵⁹ ETSI TR 101 154 V1.4, 2000, p.9.

furthermore the opinion of the DVB Consortium, that the new MPEG-4 Advanced Audio Coding (AAC) are significantly better than any of the two aforementioned standards²⁶⁰, but this format is not included due to its lack of backwards compatibility.

7.2.2.2. The Computer/networking sector

When looking at the computer sector, no timeline of similar proportions can be observed. The personal computer – originally not being a multimedia device – has moved along from having one low-quality speaker inside the desktop (with the primary purpose of going “beep” once in awhile), onto stereo sound, four channel sound and lately, also 5.1 channel sound. This has happened over a decade.

The development of computer sound standards has been characterised by the appearance of – and competition between – a number of Application Program Interfaces (or *APIs*), which are standardised sets of routines and protocols, which can be used by software designers when developing the sound components of their software.

The computer sound APIs (among which the most prominent ones in the early days were EAX and A3D) were developed with another purpose in mind than the Dolby systems. The computer APIs were meant to generate real-time sound in computer games, mimicking the sound processes taking place in various real environments. In the beginning, the effect of sound reverberation was the primary feature of these APIs. The APIs were able to generate a surround-like sound environment with two speakers only, due to their ability to generate sounds which appeared as if originating from behind the user. However, with the introduction of four speaker sound cards such as the Diamond Monster Sound in 1997, *real* surround computer sound systems became available, adding further realism to gaming.

For the computer/networking sector (focus being on wintel computers), the important events in the area of audio innovations are as follows:

²⁶⁰ Jacklin & MacAvock, 1998, p.11.

| Year | Event | Remarks |
|----------------------|---|---|
| 1992 | SoundBlaster 16 bit stereo audio card introduced by Creative Labs** | 2 (stereo) channels |
| 1995 | DirectX 1 | (Windows 95) |
| 1996 | DirectX 3 | Introduced DirectSound 3D* |
| 1997 | A3D developed by Aureal* | |
| 1997 | Diamond releases “Monster Sound” audio card supporting A3D and DirectSound3D ²⁶¹ | Four channels ²⁶² . |
| 1997 | DirectX 5 | Allows 3 rd party hardware acceleration, reducing CPU load* |
| 1998 | EAX 1.0 (Environmental Audio Extensions) introduced by Creative Labs* | |
| 1998 | SoundBlaster PCI128 and PCI64 four channel audio cards introduced by Creative Labs** | Four channels |
| 1998 | DirectX 6 | |
| 1998 | SoundBlaster Live! Series introduced by Creative Labs** | 5.1 discrete analogue channels. Dolby Digital 5.1 for external decoder. |
| 1998 | Computer games (e.g. “Unreal”) support Dolby ProLogic output. ²⁶³ | |
| 1999 | EAX 2.0 introduced by Creative Labs* | |
| 1999 | DirectX 7 | |
| 1999 | EAX 3.0 introduced by Creative Labs* | |
| 2000 | DirectX 8.0 | Incorporates EAX effects. Supports 5.1 audio ²⁶⁴ |
| 2000 | A number of EAX effects are incorporated into DirectX 8.0 | |
| 2000 | Aureal files for bankruptcy* | Aureal is taken over by rival Creative Labs.* |
| Late 2000/early 2001 | Soundblaster Live! 5.1 capable of direct decoding of Dolby Digital content onto six separate analogue onboard outputs.* | |
| 2001 | DirectX 8.1 | (Windows XP) |

Table 16: Important events in innovation in sound in the computer/networking sector. All unmarked information is from²⁶⁵. Information marked * is from²⁶⁶. Information marked ** is from²⁶⁷.

²⁶¹ Muschett & Hagén.

²⁶² Aureal.

²⁶³ No clear reference found. Indications found at www.3dsoundsurge.com/archive/week5.htm (link active per 020520). Searches at www.groups.google.com indicate that this topic was subject to particular interest in 1998.

²⁶⁴ Tom’s Hardware Page

²⁶⁵ Keam, 2001.

Particularly interesting here is, that the early four channel sound systems were dedicated *computer* sound systems, where the 5.1 channel system draw upon the Dolby Digital and DTS standards. The latter is an obvious convergence phenomenon, as it facilitates full benefit of DVD viewing on the computer.

In 1998, Creative's SoundBlaster cards were able to output 5.1 Dolby Digital through a digital S/PDIF interface. Games²⁶⁸ were able to generate this signal, but it had to be decoded in an external decoder. This was – and is – typically an integrated component with amplifier and radio tuner built in. Traditionally, these components are made by well-established manufacturers of Hi-Fi equipment (e.g. Sony, Marantz and Onkyo). Lately, the computer peripherals manufacturers and Creative Labs' subsidiary, Cambridge, have developed complete kits consisting of speakers, subwoofer and amplifier with internal Dolby Digital decoder – all specifically for use with computer, lacking the many RCA inputs for turntable, CD player, tuner and cassette deck typically found on the back of traditional Hi-Fi amplifiers.

Both 3D sound APIs – Creative Labs' EAX and Aureal's A3D – were – and are – proprietary standards. This means that the owners control who is allowed to use the APIs in e.g. computer games. As long as there is a number of competing standards, a large degree of openness can be expected (as described in the theory chapter on pages 82 ff.) as API owners want to stimulate the growth of their particular standard. With the demise of Aureal and the incorporation of important elements of EAX in Microsoft's DirectX 8.0 in 2000, the "Tweedledum & Tweedledee" standards scenario (described in Table 2 on page 65) is over. This makes the lives of software developers' easy, as they have less variables in their design. A negative effect could be that licensing agreements on using the APIs become more expensive, as fewer players (Microsoft and Creative Labs) now control the de facto standard.

With the ongoing convergence process, the surround standards of cinema and television have become relevant in computer sound design. The ability of some software of generating Dolby Digital sound may render part of the EAX and DirectX standard obsolete. Still, only *part* of them, as an API for the real-time generation of sound in virtual environments and computer games is still needed. Dolby Digital is still a system developed for stored content, without the ability of generating real-time sound patterns. The market position of Dolby's multi channel systems is somewhat different than that of the computer sound systems. This is due to the fact, that they are incorporated in large television and movie systems – e.g. ATSC and DVD, as mentioned in Table 14. Because such systems do not change overnight, it gives Dolby's standards a more "de jure" appearance, and ensures a solid foothold – not

²⁶⁶ The PC Technology Guide.

²⁶⁷ Creative Technology Ltd., 1999.

²⁶⁸ For example "Unreal Tournament".

necessarily in the convergence products and services, but at least in the television sector.

7.3. Interconnection Standards

When connecting various appliances in order to get audio and video signals from one piece of hardware to another, a number of different interconnection standards exist.

Interconnection is the connection of two elements or nodes of a network, whereby the transmission of information is made possible.

Definition 28: Interconnection (a stipulative definition).

Similar to the situation of signal standards, different standards have emerged in the two sectors. This is particularly characteristic of the video signals. Only lately, television sets have emerged, which have a connector for the VGA²⁶⁹ cable and connector of the computer/networking sector. On the audio side, things are less complex. Sound cards have from the early days made use of mini-jack connectors known from the Hi-Fi area, making it easy to connect a computer to e.g. a stereo amplifier. Interconnection standards are often related to particular signal standards. Again, there are exceptions – for example BNC connectors used for computer network cables as well as for RGB video signals.

Compared with the signal standards, the converging sectors display less fundamental differences in the field of interconnection standards. There is no distinction similar to the gap between digital and analogue in the field of signal standards. The connectors simply being the physical connection between devices transfer signals without discrimination. Still, optical connections are only used in digital signal transmission, but that is due to the fact that they emerged recently – when digitalisation of signals and equipment was well underway. An optical connection could well transmit analogue signals, too.

From the television sector, the following connector standards are notable:

- The *antenna* (or RF) connector delivers the antenna signal to the TV set's (or VCR's) tuner, where it is processed for presentation as image and sound.
- The *composite* video connector is an early means of connecting a television set and a VCR. Using a coaxial cable, all elements of the video signal are integrated into one electric signal.

²⁶⁹ It should be noted, that VGA not only is a particular resolution, it also describes the most common form of connector that connects the computer's graphics card with the monitor.

- An increased quality can be obtained with the *S-Video* (or SVHS) connector, which has separate luminance (brightness) and chrominance (colour) signals. As the composite connector, it carries video only.
- Combining sound and video, the *SCART*- or Euroconnector carries stereo sound as well as composite and S-video. Some Scart cables even carry RGB, making it possible to achieve quality superior to that of composite and S-video, if the TV set is able to accept RGB via SCART. This connector is primarily used in Europe and Australia.
- A newer form of video connector is *component* video. It consists of three separate wires, each carrying its own colour. This interconnection is widely used on High-Definition TV sets.

From the computer/networking signals, the important video connectors are:

- *VGA*, also known as “15 pin sub D” resembles the component video connector, as it carries red, green and blue separately, supplemented by horizontal and vertical sync. This standard is used by most computer graphics cards and monitors.
- *DVI* is the only digital connector among those mentioned. It has emerged among a handful of suggestions for a de facto digital connector, and is often used with flat screens and projectors. Some graphics cards have DVI output, often in the form of a connector carrying VGA as well.

In recent years, some graphics cards for computers have been equipped with composite and S-video in-and outputs, making it possible to connect e.g. a VCR to the computer or to connect the computer to a TV set, hereby using it as a monitor. The latter option is hampered by the rigidity and lack of flexibility of traditional television sets, making the picture grainy and the text unreadable.

The flexibility of sound and picture presentation standards of today’s computer systems is far superior to that of the television sector. This makes for a much wider space of operation for those developing new applications and services for computers compared to the television sector. This property is not necessarily a driver for convergence. It might instead lead to a *migration* of television content onto computers, as a supplier wanting to deliver content of increased modality might aim at having people view the content on computers instead of television set.

Genuine convergence might rather be achieved by having television sets accept a VGA signal, or achieving a future unified standard for video interconnection for use in both sectors – but that might on the other hand reduce the set to a computer monitor. It is a question of definition of *which* appliances belong to *which* sectors – and raises questions like “what makes a TV a TV?”

7.4. Content Standards

Communicating or consuming information on appliances of various sectors is not merely a question of the appliances themselves. The content of the communication process or information also needs to fit the appliances (or vice versa). Here, a number of issues are relevant, if one wants to understand the problems of convergence.

The content is the information contained in the signal - e.g. a movie, in the case of television or a conversation, in the case of telephony.

Definition 29: Content (a stipulative definition).

7.4.1. Storage Media

A very tangible standardisation case is provided by the storage media of communication and information appliances. These media contain the information that can be viewed, listened to or in other ways consumed by users. Storage media have their primary relevance in relation to *information consumption* in *hardware/software systems* rather than *communication* in *communication networks*, as their purpose is to contain information, which can be used mainly in watching movies or listening to music. The storage media of the computer sector are furthermore used for files such as documents, programmes etc, and these functions were actually the originally intended. With the development of the CD-ROM (and its TV sector equivalent, the music CD in the eighties), an early manifestation of the convergence process could be observed.

Medium: *something (as a magnetic disk) on which information may be stored.*

Definition 30: Medium (a lexical definition)²⁷⁰.

If looking at the storage media for the TV sector, one will notice that they are *single purpose*. The VHS and Betamax video tapes are, for example purpose-specific media, meaning that there is a sharp affiliation of one medium type to one particular form of information. The video tapes are specifically developed for the one purpose of holding *analogue video streams*. When turning one's attention towards the storage media of the computer/networking sector, one could argue, that it's media, too, are single purpose: They are designed to hold digital *files*. This is indeed correct – though newer digital tape formats (Such as Sony's DV format) hold digital streams.

²⁷⁰ Merriam-Webster OnLine. – Note that this is the second definition of medium or media in this dissertation. The term “storage medium” is used when necessary to avoid confusion.

The point is, however, that the files held by the computer/networking sector's storage media can contain information in a wide array of formats as opposed to the rigid limitations of the video formats of earlier days.

In the early days of video recorders (i.e. the 1970's and early 80's), the video industry launched a number of different playing times and qualities. The fact being, that for a given length of tape, there was a trade-off between playing time and picture quality, the industry players sought to strike the right mix of time and quality by adjusting tape speed. Fortunately, no users were left with unusable equipment – an old video recorder could still play any tape (provided, of course, that the tape was of the correct standard: VHS or Betamax), only would the playing time be short – but then, on the other hand, the quality would be better.

Example box 3: The trade-off between playing time and quality.

In the computer/networking sector, a similar trade off can be observed today. Video on computers is usually compressed for space-saving purposes. Like in the video recorder case, there is a trade off between space and quality. If for example one is holding video files on a hard disk, it is a question of preferences how much the video files should be compressed. A decrease in video quality would leave room for more video files. Issues such as these are explored to a greater depth in the “The TVPC Case Study” chapter.

The analogue videotapes have to a great extent been replaced by digital media. Initially, these media carried pre-recorded movies, and were not intended for recording purposes. Early media, Video CD and Super Video CD (VCD and SVCD) were based upon the CD-ROM, and content was encoded in MPEG or MPEG2. Neither of these format reached great adoption. The big shift in media for pre-recorded movies came with the DVDs containing material in considerably higher quality than what was known from pre-recorded VHS-tapes.

Below can be seen the important parameters of the digital media formats. Included in the table are also DV, which is a digital consumer camcorder format, and DivX, which is an MPEG4 based video codec, used by many hobbyists for video compression, and notorious for being the preferred format for illegally copied and distributed movies.

| | VCD | SVCD | X(S)VCD | DivX | DV | DVD |
|--------------------------|--------------------|--------------------|--------------------------------|---------------------|--------------------|--------------------|
| Formal standard? | Yes | Yes | No | No | Yes | Yes |
| Resolution PAL/NTSC | 352x240 352x288 | 480x480 480x456 | 720x480 720x576 or lower | 640x480 or lower | 720x480 720x576 | 720x480 720x576 |
| Video compression | MPEG-1 | MPEG-2 | MPEG-1 or MPEG-2 | MPEG-4 | DV | MPEG-2 |
| Audio compression | MPEG-1 | MPEG-1 | MPEG-1 | MP3 WMA | DV | MPEG-2 AC-3 |
| MB/min | 10 | 10-20 | 5-20 | 1-10 | 216 | 30-70 |
| DVD Player compatibility | Very good | Good | Good | None | None | Excellent |
| How CPU intensive | Low | High | High | Very high | High | Very High |
| Quality | Good | Very good | Very good | Very good | Excellent | Excellent |

Table 17: Digital video/audio media formats comparison²⁷¹.

7.4.1.1. Future Storage Media

With the arrival of HDTV, a storage medium that can easily accommodate the high-resolution information is desired by many users. A logical successor to the DVD, the HD-DVD is under development, but agreement upon the exact format has not been reached. The consortium responsible for developing the DVD standard – the DVD Forum – is split into two camps with differing opinions on the appropriate way to deliver pre-recorded movies on disc in the future.

By early 2002, a group consisting of Hitachi, LG Electronics, Matsushita²⁷², Pioneer, Philips, Samsung, Sharp, Sony and Thomson are in favour of replacing the physical media and drives with a new high-capacity disc standard called Blu-Ray. This format

²⁷¹ PC Tech Guide.

²⁷² Matsushita is better known under its brand name Panasonic.

would have a capacity of over 20 GB and would utilize the well-known MPEG2 format already used in HDTV and today's DVDs.

The remaining members of the DVD forum, among whom the most prominent is Toshiba, prefers keeping the existing DVD format with the exception that the disk should have two layers instead of one – giving a capacity of 9GB. The High-Definition content should be made to fit this comparably smaller medium by the use of considerably modified MPEG2 compression – or by using the newer MPEG4 compression.²⁷³

Which among these two formats – if any – will be the format of the future remains to be seen. The factors influencing the outcome of this standardisation process are complex, and other industries than the hardware manufacturers – most notably the movie industry - are interested in influencing the process.

No matter what the future optical disc format is, it is likely, that it will be playable on a computer as well as on TV sector appliances, as drives and software must be expected to be available. At least, this was the case when DVD was introduced: In most parts of the world, DVD drives for computers were available at the same time – or often even before – stand-alone DVD players became available.

A quite different, and “anti-convergence” phenomenon has however been introduced. This is the *Digital VHS* or D-VHS, which has been released by JVC in the beginning of 2002. Supporting formats such as 720 lines progressive and 1080 lines interlaced, it is a good match for the HDTV broadcasts. Apart from the usual connectors for older television sets, it has FireWire (a.k.a. i-Link or IEEE1394) as well as component video outputs. It is targeted for the U.S. HDTV-owning segment, which is expected to reach four million per 2003²⁷⁴.

This new format is supported by part of the Hollywood movie industry – but only part of it. Fox, Universal, DreamWorks and Artisan plan to release a number of movies on the new format in the summer of 2002, while Columbia and Warner have no plans of supporting D-VHS²⁷⁵. D-VHS does however have one very important aspect in its favour: It's available, where by contrast, agreement hasn't yet been reached on the new disc standard. According to W. Brian Arthur's positive feed-back theory mentioned on page 65, gaining an early lead is crucial, when incompatible technologies are competing for the same market. If the DVD forum intends to control the future High-Definition storage medium, they must have not only a standard in place not too long after JVC and its supporters. The standard itself is not enough: to be able to offer an attractive alternative to D-VHS, support for the new disc-based format

²⁷³ Information about future DVD formats is from Hara, 2002 .

²⁷⁴ BBC News, 2002.

²⁷⁵ Sweeting.

from content providers – thus ensuring sufficient availability of titles – is also necessary.

The future of digital media is rather unclear at this time. There is the possibility of a new disc based medium arriving. If, on the other hand, D-VHS gains sufficient support among content suppliers – i.e. first and foremost Hollywood – it might gain a sufficient installed base to discourage the adoption of new disc based media. This outcome must be expected to hamper the progress of convergence, as the dominating media will depend on a stand-alone appliance, which – though being able to interface to a computer through FireWire – primarily is targeted towards the television sector.

7.4.2. Connections to content sources

Basically, there are two ways of gaining access to the content displayed on television sets and computers. One is the above-described use of storage media holding the information to be consumed. The other way is via a connection to an external source.

In the computer/networking sector, connection to content stored outside of the computer is traditionally achieved via computer networks – hence the name of the sector. These LANs (or Local Area Networks) deliver digital information in the range of 10 to 100 mbps. With the coming of WANs (or Wide Area Networks), computers are able to interconnect globally. Here, other networks assume the roles of information channels: Modems provide Internet and computer-to-computer connection via the telephone system; cable modems do accordingly via the cable TV network. Lately, there has been an increase in the establishment of dedicated broadband computer WANs giving users high-speed access to data from all over the world.

The television sector has until recently had three ways of connecting to external sources: Cable, terrestrial antenna and satellite. All three ways are traditionally intended for one-way communication: Delivery of television programmes to private homes. Due to the increasing need for Internet access, cable networks and satellite connections have been adapted for the two-way communication needed for common Internet use²⁷⁶.

Recently, a migration from analogue to digital television signal transmission can be observed. Due to the large installed base of analogue home TV sets, digitalisation is more widespread in value chain links prior to the final consumption of the television signal. A transition towards a start-to-end digital TV system is in progress. In Europe, the DVB system is under implementation, in terrestrial, cable as well as satellite versions. This holds promises of a better bandwidth utilisation plus the possibilities of more interactive forms of television.

²⁷⁶ Even in its most basic form, *surfing*, a return path is necessary to inform the web servers which documents the user wants to download and view.

Especially in the field of interactivity, the computer/networking sector is ahead of the television sector. Communication between computers is traditionally two-way and symmetric, whereas the content of television usually is delivered to the consumer with little possibility of influence on the presentation. The only form of interactivity – apart from recent experiments among a number of TV stations – is the so-called *carrousel interactivity* provided by the choice between channels or teletext pages.

The future might bring a migration of television content onto appliances and communication infrastructures belonging to the computer/network domain. However, a form of convergence leading to hybrid communication forms is another possible outcome. Here, one can imagine that the content suited for interactivity and personal choice is transmitted via computer-type networks, while the content of more general interest will be transmitted via channels belonging to the television sector. These aspects are examined in greater detail in the Hybrid Communication and Information Case Study.

7.5. Hardware and content – a chicken-and-egg problem

The modality in the communication or information consumption process itself is usually limited by both the modality in content and the modality capabilities of the appliance. If the content supplier is another human with whom one has a phone conversation, the modality is limited mainly by the appliance – e.g. the telephone. The facial expressions and gestures of the communicating parties can't be displayed on a traditional phone.

One of the classic catches in the introduction of new and improved standards is the chicken-and-egg problem. In order for a new standard to succeed, there must be a sufficient supply of the goods that must be available in order for the new service or product to work²⁷⁷. This problem applies in all scenarios where products or services do not function by themselves, but require certain components to function – i.e. they are hardware/software systems as defined by Katz & Shapiro on page 73.

Compared to the TV sector, the computer/networking sector seems to easier overcome these problems. If one looks at innovations in signal standards in the TV-sector, they are scarce and far between. In the sixties, colour television began to gain momentum, in the late seventies and early eighties, stereo sound became widespread on TV sets, and at present, the attempts of introducing widescreen television can be observed. Some of the introduced improvements in signal standards have succeeded, others have failed.

The difficulties of introducing new resolutions, refresh rates, colour depths and sound definition in the TV sector is due to the fact that in order for the new standard to gain

²⁷⁷ Also referred to as “Specialised Assets”

adoption, there has to be a sufficient installed base of TV sets capable of utilising the new standards and the improvements it brings. On the other hand, consumers are unlikely to purchase such hardware unless there is a sufficient supply of programmes.

With the considerable price of television sets, consumers are bound to be conservative in pioneering new standards. No one likes the perspective of being stranded with unusable and expensive equipment. Therefore, in order to convince customers to buy new hardware, the content providers must ensure that customers actually *trust*, that the new standard will prevail. This is most likely to be obtained by sticking with the new standard and for example sending widescreen programmes for a long period of time even though only a small percentage of the viewers can actually benefit from it. This is costly for the content suppliers and related industries, and leads to a conservatism concerning new signal standards. One wants to be absolutely convinced before throwing money at a new standard.

In the computer/networking sector, things are quite different. The distributed intelligence in appliances (the CPUs of the computers) gives the computer a processing power based on software rather than hardware. Hence, the computer is way more flexible in accepting new standards. This can often be obtained by simply installing the appropriate piece of software. In some situations, a movie file based on a new standard will prompt the player software to download the appropriate codec²⁷⁸ via the Internet. It goes without saying that this is way cheaper than the TV sector's alternative, which is purchase of a new piece of dedicated hardware.

Computers are – as mentioned earlier – further flexible in the sense that colour depth, resolution and refresh rates aren't fixed, but can be adjusted in accordance with the properties of e.g. the media clip played. Introduction of high-resolution content would be a trivial matter on computers, provided the sufficient processing power and monitor quality is in place.

There are however limitations to the flexibility of computers. A certain amount of processing power is necessary to decode formats with advanced compression algorithms, and this power isn't always available in older computers. Aspect ratios can also pose a limitation on computers. The vast majority of today's computers use 4:3 monitors, and though they're perfectly able to display e.g. a 16:9 video clip, this will imply black top and bottom bars on the screen.

Also when viewing TV signals on the computer, there is a problem not easily overcome. Due to the progressive scan nature of computer monitors; the interlaced contents of traditional television signals can lead to frame tearing artefacts. This is

²⁷⁸ Compressor/DECompressor.

neither a big problem²⁷⁹ nor an obstacle to convergence or migration, but still serves as an example of the computer's limitations.

In the field of more exotic increases in modality, the standard computer can't display various forms of multi modal content by software alone. Innovations such as stereoscopy by means of shutter glasses or surround sound by means of multiple speakers needs additional hardware (at minimum the glasses or speakers themselves) to work.

7.6. Conclusion

Evolution takes place at a much faster pace in the computer/networking sectors because of the inherent flexibility of signals – there is no single signal standard, so initiatives aiming at improving TV modality have good chances of functioning on computers. The appliances (computers and monitors) are usually already able to handle improvements over traditional TV modality, because colour depth, refresh rates and resolutions aren't fixed as in the case of television. The TV sector's standards are by contrast quite rigid when attempting improvements, leading to large costs of introduction of new standards and a thereof derived conservatism on behalf of the actors involved.

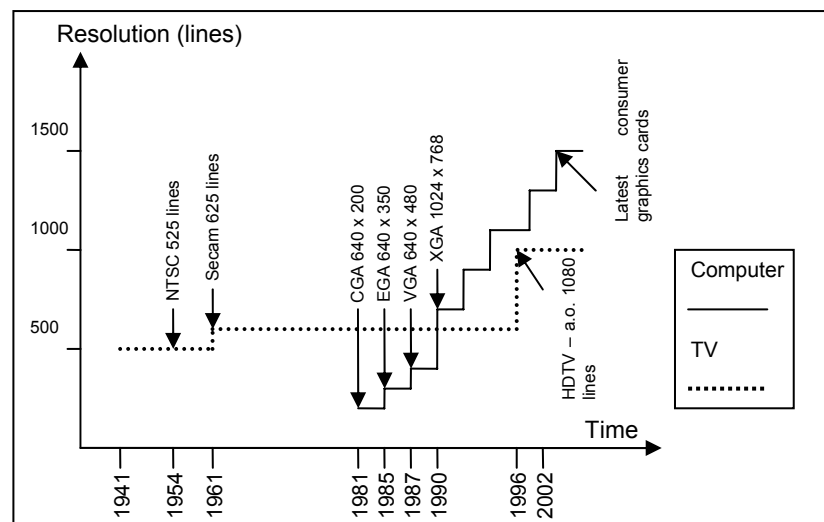


Figure 24: Innovations in resolution in the television and the computer/networking sectors²⁸⁰.

²⁷⁹ There is software available that specifically aims at eliminating frame-tearing artefacts when viewing TV signals on a computer.

This can be illustrated by mapping the dates of the most important advances of screen resolution in the two sectors, by which one can observe much larger “steps” in the television sector’s graph than in that of the computer/networking sector. This finding can be attributed to the fact that because a TV set is not able to use other resolutions than the one it was originally developed for, the users would be stranded with unusable equipment when a new resolution was introduced. Considering the large installed basis of TV sets in the households, an improvement in resolution has to be sufficiently noticeable to justify the replacement of that many appliances. The computer sector, by contrast, is characterised by appliances so flexible, that an incremental increase can be introduced without stranding users. Those, whose monitors are unable to display the new resolution will have to settle for a lower one – but their appliance is by no means rendered useless.

TV content suppliers are at present experimenting with making programmes interactive. A convergence of TV and computer/networking with common signal and appliance standards might bring this interactivity by through the back door. Either migration of TV content onto computer networks or hybrid transmission forms can aid the interactivity initiatives of content suppliers through the use of internet-type communication methods.

A number of obstacles to the convergence or migration of TV content onto computers exists. In the computer sector, the size of storage media poses a limitation to the picture quality of Hollywood-type movies – and thus poses an obstacle to using the computer as a TV/VCR type device. Here, the existence of a securely established video standard limits the chance of new higher capacity standards emerging.

Among the signal standards, a number of different standards have been identified, which pose obstacles to the cross-sector communication and information consumption:

- Aspect Ratio: Most computer use 4:3, new television standards use 16:9
- Scan Method: Computers use progressive, some versions of DVB and HDTV use interlaced.
- Number of audio channels: Computer surround systems use four loudspeakers, most systems of the television sector (e.g. Dolby Digital) use 5.1.

²⁸⁰ A number of steps of the computer resolution graph is not accounted for. This is due to the fact, that the computer industry abandoned the “naming” of resolutions (e.g. “CGA, VGA”), in favour of simply allowing incremental increases – usually with the introduction of successive major graphics chips design. These resolutions were then referred to as e.g. “1600x1200”. The exact times of the resolutions between XGA and today’s 2048x1536 are unknown, and the corresponding steps should be seen as illustrative.

- Pixel format: Computers use square pixels, some version of DVB and HDTV use rectangular pixels.

These are all problems that can be remedied by means of conversion, but this almost always implies a decrease in quality.

The lack of a European high-definition television system might lead to either the adoption of the North American standard or the migration of high-definition content onto the appliances of the computer/networking sector. For this to happen, it is necessary that European consumers can actually access the content –by access either to transmissions (via satellite, cable, terrestrial or internet) or to storage media, e.g. in the form of high-definition DVDs or video tapes.

Other less important technical limitations have also been described here, limitations, which might well be solved by the implementation of already existing digital video standards. There are other obstacles beside these purely technical ones: Strong copy protection initiatives from content providers could for example also hamper the development of computers as true multimedia devices.

Viewed as hardware/software systems, the success of future appliance standards highly depends on the availability of compatible content – and no less importantly: vice versa. Clearly defined and widely accepted content and hardware formats are a necessary precondition for the success of future infocom standards.

8. The TVPC Case Study

One of the results of convergence most visible to end users is the possibility of using the appliances of one sector for purposes traditionally belonging to another sector. This is the *promise of interoperability*, which is described on page 3. This case study explores the possibility of using a computer in the way a television set and its related components such as VCR and satellite tuner are used.

With its focus on picture resolution and other quality related issues, this case study also serves to describe the topic of incremental quality improvements, thus also answering part of the *quality promise*. The radical innovations in the field of quality are however treated in “The Modality Case Study”.

The case study identifies a number of areas, where the appliances of the two sectors differ, and where obstacles to convergence might occur. It also describes the strengths and weaknesses of the appliances and content of each system, identifies possible future development paths and puts the findings into the perspective of the selected theory and formulated research questions.

Much of the development of standards, products and services relevant to this case study has been described in the “Signal, Interconnection and Content Standards” chapter. The TVPC case study draws heavily upon this chapter, and goes into further detail with the issues that are relevant to the particular problems and opportunities of using a PC for traditional TV sector purposes.

8.1. Introduction

A modern personal computer has both a monitor and a set of loudspeakers. So does a television set. This leads to the obvious observation, that the content intended for one appliance might well be consumed on another. Using the computer as a TV set and vice versa are possibilities.

Both forms of convergence have been attempted to considerable extent. Should one form prevail over the other, it would be an important step in the direction of that particular sector’s dominance in the convergence process. No clearly identifiable outcome of this competition can be observed, as pointed out by the European Commission:

Whether the PC/TV or the TV/PC will win this battle is, at the moment, quite unclear. What is certain however is that the consumer's "home platform" is set for significant evolution over the next few years.

Quote box 7: The European Commission's view on the appliance convergence between computers and television²⁸¹.

This case study focuses on one of the forms, namely the TeleVision Personal Computer – or TVPC. It identifies the fundamental capabilities necessary for a computer to undertake the tasks of traditional television equipment, and assesses the computer's ability to do so. The study is guided partly by actual experiments with configuring, assembling, using and fine-tuning TVPCs²⁸² as explained in the "The TVPC Proof-of-Concept Prototype" in the appendix, partly by information gathered from manufacturers, content providers and user groups.

8.1.1. A modular vs. an integrated approach

An important difference between the appliances of the two sectors of television and computer/networking has to do with the way the hardware is configured. While a television set usually is purchased as an integrated unit – i.e. one box containing a CRT, loudspeakers, a tuner, a power supply and a number of other components, computers are more flexibly configured. The consumer has an option of mix-and-match when selecting VCRs and satellite tuners for the TV set, but the components themselves are not suited for replacement of chipsets, installation of alternative software etc.

When private consumers choose a computer, there are two fundamentally different approaches. The consumer can choose a readily assembled computer with components selected by the manufacturer. These are often brand names, such as Dell, Compaq or IBM. Alternatively, the consumer can select the individual components (case, motherboard, sound card, CD-ROM drive etc.), and thus let his own preferences influence the performance (and price) of the computer. While the latter approach mostly is characteristic of the enthusiasts, both computers are equally upgradeable.

The TV sets and the household computers display many differences, especially in relation to the opportunities of "tailoring" an appliance. Here, the mix and match approach of the computer sector allows the TVPC to be adapted to almost whatever purpose²⁸³ the user might desire. A tendency, which can be observed lately, however,

²⁸¹ The European Commission, 1997, p.14.

²⁸² The focus here are Wintel PCs, not e.g. Linux or MacIntosh.

²⁸³ E.g. terrestrial or satellite television, time shifting on an internal hard disk or recording to external media – e.g. CD-R.

is the integration on the motherboard of the functionalities traditionally carried out by add-in cards. With built-in graphics, sound, network and hard disk controller circuits, the flexibility of the computer in terms of tailoring the hardware is diminishing. This tendency has not become dominant, and might indeed never be – but still, it is a step towards less flexibility.

8.2. Requirements of TVPCs

There are a number of fundamental requirements, which a computer must fulfil in order to function as a television set. In order to be able to properly compare how the computer and the TV set fulfils these requirements, they have been ordered into four categories:

- Input capabilities
- Output capabilities
- Control capabilities
- Storage capabilities

Within these four groups, the study examines the computer's ability to match the traditional television appliances, and identifies areas where the computer has particular advantages and the television systems particular drawbacks²⁸⁴, which might stimulate a movement towards increased viewing of television content on computers – and thus bring about a migration. The case study furthermore investigates indicators of a more “true” form of convergence in the form of appliances, which integrate elements of both sectors (e.g. appliances such as TiVo and Nokia Media Terminal, described later in this chapter). Finally, obstacles to convergence are identified.

8.2.1. Input capabilities

The *input capabilities* have to do with the kind of signals, the appliance is able to accept. Traditionally, television broadcasts come in analog forms via cable, terrestrial antenna or satellite. Recently, all three media of transmission have emerged in digital forms, supplementing the analog transmissions²⁸⁵. For a computer to be fully capable of doing the work of a TV set plus its supporting hardware, the computer should be capable of accepting all these forms of signals.

²⁸⁴ These advantages and drawbacks are candidates for "Scientific Advances" as described by Dosi on page 5 and "Reverse Salients" as described by Hughes on page 5 - both potentially leading to a system or paradigms shift in case the television content migrates to the computer platform.

²⁸⁵ Digital transmission is widely expected to take over from analog at some time in the future, but the state of implementation as well as the roadmaps for the transition differ considerably among regions and countries.

For a computer to be able to show a television broadcast, it needs a component that can turn the electric signal of a TV cable or the electro-magnetic waves of antennas and satellites into a form usable on the computer. This task is usually undertaken by a so-called *TV tuner*. In its most common form, a TV tuner is an electronic circuit board that fits in the PCI bus on the computer's motherboard. It has an input connector for the coaxial cables connecting to the cable network, antenna or satellite dish. In some cases, the TV tuner has sound and video outputs, but often, the outputs of the computer's graphics and audio cards are used for delivering sound and video to the sound and display devices.

An alternative solution to the internal TV tuner card is an external tuner, delivering signals via USB ports. This is particularly useful with laptop computers, which have no space for adding an internal tuner card. A third alternative – though not practical considering the wide availability and low prices of TV tuner cards – is connecting a VCR to a video input (Composite or S-Video) and the sound card's audio inputs. The USB solution will not be investigated further here, the focus on this project being home appliances. Neither will the VCR solution be discussed, as it is quite impractical.

The area of TV tuner card software is remarkable because there is a number of software developers outside of the community of established hardware and software developers. These pieces of software excel in being able to incorporate the latest developments in drivers and codecs, hereby enabling the user to tweak his hard disk TV recording to maximal efficiency.

Still, the capability of a TV tuner card to process a certain incoming signal lies in its hardware. Here, we have a number of different layouts, depending on the standard of television (PAL, NTSC, ATSC HDTV, DVB), as well as the delivery channels (cable, terrestrial and satellite).

8.2.1.1. Analog TV Tuner Cards

The most numerous types of TV tuner cards in use are those that accept analog terrestrial or cable signals. They are controlled by a piece of software from which the user can switch channels and adjust settings. The pieces of software developed by TV tuner card manufacturers have these basic functionalities plus in some cases the option of recording TV programmes to the computer's hard disk.

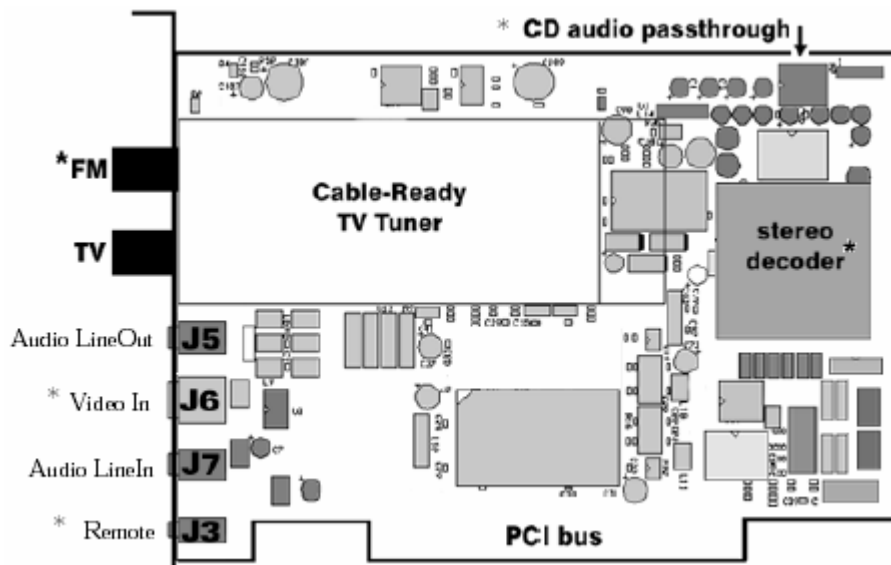


Figure 25: Typical layout of analog cable/terrestrial tuner card²⁸⁶.

The older, analog formats of PAL and NTSC can be viewed with a wide range of TV tuner cards. One feature distinguishing these cards is whether the sound is mono or stereo. If the card has stereo sound capability, it also gives the option of Dolby Pro Logic surround sound, which is contained in the stereo sound signal.

Another feature distinguishing analog TV tuner cards is the option of an on board video encoder chip. This is useful when the viewer wants to not only *view* the programmes, but also wants his computer to be able to *record* the programmes for archival and later viewing. Having such a chip on the card takes much of the load off the CPU, when the TV programme is encoded and stored on the hard disk. A drawback is the lack of flexibility in choice of compression algorithm, as the decoder chip usually is suited for one compression standard only (e.g. MPEG2).

The analog tuner cards have been available since the middle of the 1990s, and the innovations are slow and far between on the hardware side. Most tuner cards use the Brooktree 848/878 chip, and have done so for a number of years. This eases the job of software manufacturers, as the need for multiple software versions, tailored for many different tuner cards, is reduced. It is not likely, that more innovations will be done in the field of analog TV tuner hardware, as most countries have plans for a move to digital transmissions, hereby reducing the research and development incentive among analog hardware developers.

²⁸⁶ Hauppauge Computer Works, p.1.2.

When selecting an analog TV tuner card, the user must choose, which delivery channel, he wants to use. Cable and terrestrial analog television can be viewed with one card only – they all are capable of processing both signals, which are essentially identical. If the user wants to be able to view satellite channels, a dedicated satellite tuner card is necessary. Here, the range of choice is considerably narrower than is the case with cable/terrestrial tuner cards.

8.2.1.2. Digital TV Tuner Cards

The arrival of digital television is matched by the development of corresponding TV tuner cards for European as well as North American standards.

Due to the different standards for digital television chosen in North America respectively Europe, the market is characterised by two families of TV tuner cards. Here, it is important to note, that these standards aren't actually competing, as they are intended for two geographically separate markets. A standards war with positive feedback and tipping effects can thus not be expected immediately.

The U.S. market is characterised by a handful of different makes of HDTV tuner cards. Most are intended for terrestrial broadcasts, though many claim in one form or another also to support cable and satellite (though, when this claim is examined closer, it appears that they connect to cable or satellite set-top boxes). Examples of manufacturers²⁸⁷ are AccessDTV, Telemann and Macro Image Technology. Neither of these three state clearly whether the cards can be used for satellite and cable without interfacing with some form of set top box. These cards accept the most common American HDTV and SDTV formats. The Telemann card, for example supports 1920 x 1080 interlaced and 1280 x 720 progressive in 16:9 aspect ratio, and furthermore 720 x 480 progressive, 1440 x 1080 interlaced and 1024 x 768 progressive in 3:4 aspect ratio²⁸⁸

The European market, by contrast, is characterised by clarity concerning the capabilities of the digital tuner cards. This is due to the very clear specification of the three sub-standards of DVB: Terrestrial (DVB-T), satellite (DVB-S) and cable (DVB-C). For each type of DVB, there are a number of tuner cards available. These cards have the capability of displaying the programmes on the computer monitor, a TV set (if the appropriate output is available on the card or the computer), or a projector. Furthermore, the user has the option of recording the programmes to the computer's hard disk. This is not in itself different from the capabilities of the analog tuner cards,

²⁸⁷ Web sites at www.accessdtv.com, www.telemann.com and www.twinhan.com.

²⁸⁸ Global Telemann Systems, Inc.

but in the case of DVB, the stream of audio and video data are written directly to the hard disk, without the quality loss and CPU stress implied by analog capture²⁸⁹.

Most of the newer cards either have a built in CI (common interface) module, or can be fitted with one. In this module, a pay-TV subscriber can insert his smart card, enabling the viewing of encrypted pay-tv programmes. There are rumours that the encryption schemes have been cracked or circumvented, hereby making it possible to see pay-TV on the computer without a smart card²⁹⁰.

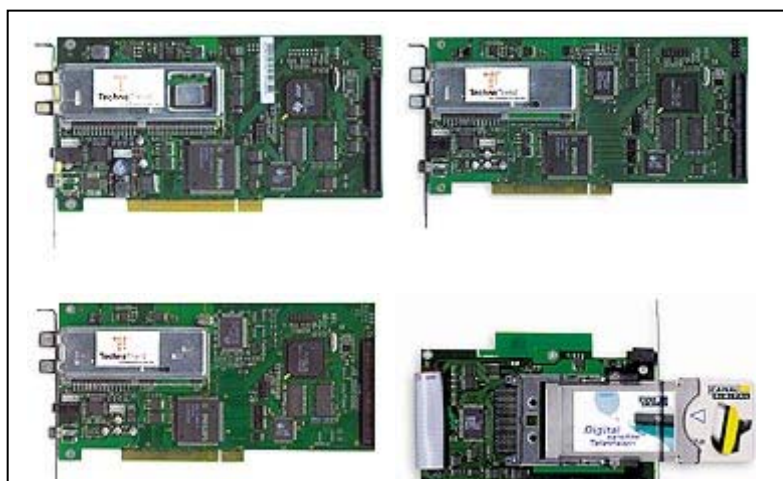


Figure 26: TechnoTrend's DVB-S, DVB-T and DVB-C cards and CI module.²⁹¹

Apart from the television programmes themselves, the cards deliver teletext, electronic programme guides, and in some cases Internet access. For the latter, however, an agreement with an ISP (Internet Service Provider) and the setup of a return path (e.g. phone or ISDN) is necessary.

In the DVB field, many of the digital cards provide room for future increases in resolution and frame rate if the broadcasters at some point in time decide to deliver programmes resembling the North American HDTV. Ironically this applies to the cheaper range of DVB cards rather than the expensive ones. The reason for this is, that the cheaper ones rely on the computer's CPU to do the decoding, while the more expensive ones have built-in hardware decoder chips – hence the higher price²⁹². The cheaper cards can have their resolution and frame rate capability increased by software

²⁸⁹ Scheffel, 2001.

²⁹⁰ See e.g. Scheffel, 2002.

²⁹¹ TechnoTrend website (online reference: www.technotrend.de – link active per 020605)

²⁹² Schick, Daniel, TechnoTrend AG, in an email reply to an inquiry about the “future-proofness” of their range of DVB tuner cards, June 2002.

updates, while those with built-in hardware-decoders must be replaced. This is a very interesting aspect, when examining the innovation potential of the two sectors. With a large installed base of PAL and SECAM TV sets in Europe, broadcasters will be reluctant to increase resolution and frame rate (and switch to progressive scan), as no users will be able to enjoy the increased quality on their TV sets. If, however, there is a sufficiently large base of PCTV users with flexible tuner cards, watching the content on flexible and highly capable display devices, there is at least *some* incentive for “High-Definition-DVB”.

The TV tuner cards, analog as well as digital are the most crucial components in the form of convergence that implies viewing television content on computers. Not only can they make the computer do most anything the stand-alone appliances of the television sector can, they also can take advantage of the calculating and scaling capabilities of the computer, the flexible storing options and in some cases, even internet access.

8.2.1.3. TV Tuner Software

For the TV tuner cards to function, they need a set of software to be installed in the computer’s operating system. All consumer TV tuner cards come with a piece of software supplying at least the fundamental facility of viewing television on the computer. Many pieces of software also give the user the ability of recording a television programme to the computer’s hard disk.

While there is little difference between the pieces of hardware (the tuner cards) apart from the two distinctive groups of analog respectively digital cards, the software are crucial in making viewing and recording work effectively and smoothly. Three main areas, where TV tuner software can excel, can be identified:

- User Interface.
- Viewing
- Recording

In the following, a number of TV tuner card applications are presented. They each focus on one particular aspect of television functionality on computers. They are all 3rd party products, meaning that these are not the pieces of software, which accompany the tuner cards. Most are downloadable from the Internet and can be registered for modest fees. The reason for focusing on 3rd party software is, that it is in this area, the most radical software innovations in TV to PC convergence can be observed.

Application: A program or group of programs designed for end users.

Definition 31: Application (a lexical definition)²⁹³.

The user interface provides the user with a means of interaction with the computer. There are a number of different layouts – some trying to make the TV tuner software look like a television set, some sticking to the classic windows layout. One of the more interesting pieces of software is ShowShifter, which is designed to work well when a TV set connected to the graphics card's TV-out is used as monitor. It has few, but large buttons to operate. The rationale behind this layout is, that television, though it might be received and recorded on a computer, usually is viewed from a sofa, on a traditional television set connected to the composite or S-Video available on many computers' graphics cards. The software can easily be operated with a computer mouse only, but advanced infrared remote control systems²⁹⁴ can also be fitted to the computer.



Figure 27: The ShowShifter user interface.²⁹⁵

ShowShifter is a piece of software for viewing as well as recording television programmes. One of its primary features is the possibility of “show shifting” – hence the name – i.e. the ability of pausing a live transmission and resuming it at will. Other pieces of software focus on the recording capabilities. IUVCR²⁹⁶ and WinVCR²⁹⁷ are

²⁹³ Webopedia.com.

²⁹⁴ For example Girder – see <http://www.girder.nl/index.php> - link active per 020606.

²⁹⁵ (online reference: <http://www.showshifter.com/showshifter.htm> - link active per 020606)

²⁹⁶ (www.iulab.com - link active per 020606)

²⁹⁷ (<http://www.ravisentdirect.com/store/cpdvvp.html> - link active per 020606)

examples of these (it is obvious that the names of these pieces of software are made with the purpose of associating with the video cassette recorder – the “VCR”).

An application that also has recording capabilities is SnapStream. It however has another feature distinguishing it from other pieces of TV tuner software. This is the possibility of encoding and streaming the TV programmes over a computer network, thus acting as a video server. This feature makes it possible for e.g. the employees of a company to watch a particular TV programme on their computer by opening their video player software (e.g. Windows Media Player, which is installed on most newer Windows computers), and connecting to the SnapStream video server. It, however, also makes possible a new form of intellectual property violation: the streaming of live events such as pay-per-view boxing matches over the Internet²⁹⁸.

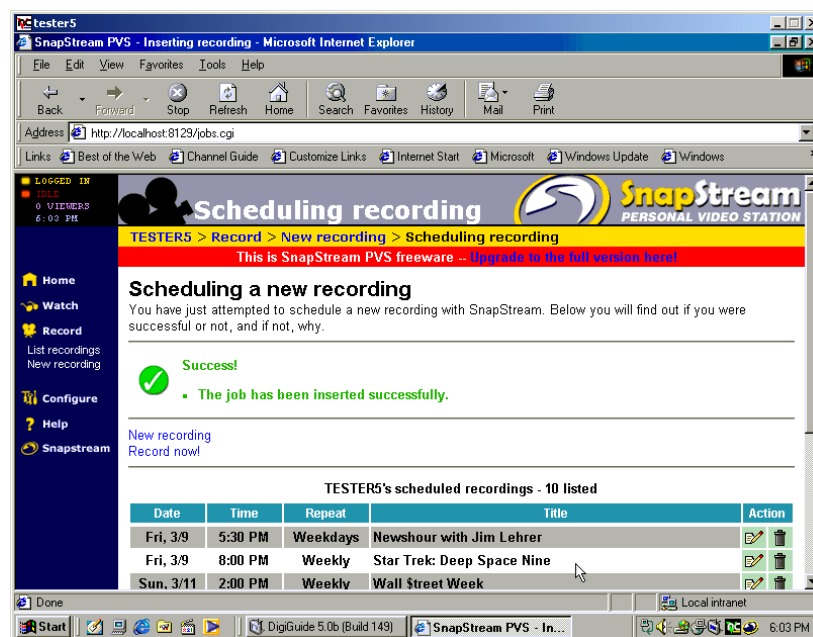


Figure 28: ShowShifter recording schedule.²⁹⁹

ShowShifter and SnapStream have an interesting feature in common. They both incorporate online television guides on the Internet, making it possible by connecting to the television guide’s website, with a few clicks of a mouse to schedule the

²⁹⁸ The extent of this violation has not been investigated very deeply in this project, as it is not particularly relevant to the research questions. It nevertheless opens for a whole new area of effort to the pay-TV providers, who so far have concentrated their efforts on preventing the manufacturing and distribution of unauthorized smart cards.

²⁹⁹ (<http://www.interrorem.com/labrat/images/digiguide-plugin4.gif> - link active per 020606)

recording of a television programme. This integration of web information and television is a powerful example of useful convergence, providing features and ease of operation that the traditional television appliances are incapable of.

This possibility receives much attention from the European Commission – planned and discussed in the television sector, but here put to actual use via the hardware, software and Internet of the computer/networking sector.

[Navigation systems] form two distinct market segments - Browsers and search engines are tools for exploring Internet web pages, whereas EPGs represent the electronic “zappers” of the future, guiding viewers through a myriad of digital television programmes and channels.

Quote box 8: The European Commission's distinction between navigation systems in the computer/networking and the television sectors³⁰⁰.

This is a feature available only to those who have their country's TV channels listed in the online TV guides supported by these two applications. At present, SnapStream supports Digiguide³⁰¹ for the U.K. and North Ireland as well as TitanTV³⁰² for the U.S., while ShowShifter supports Digiguide only. Residents in other countries can hope for online TV guides to present their content in a format that is easy to incorporate by the TV tuner software, giving the rest of the world services similar to those existing in UK, North Ireland and USA.

³⁰⁰ The European Commission, 1997, p.24

³⁰¹ (<http://www.digiguide.com/> - link active per 020606)

³⁰² (<http://www.titantv.com/> - link active per 020606)

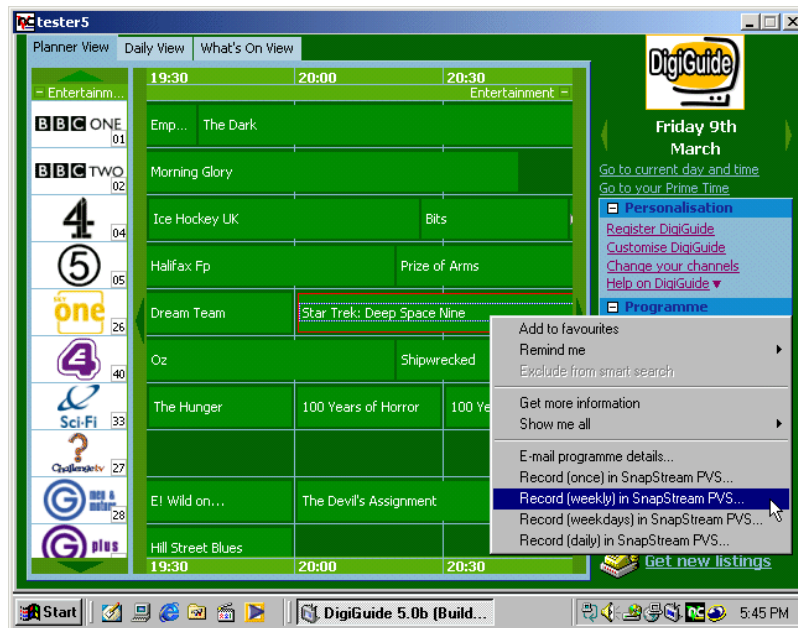


Figure 29: DigiGuide used for scheduling SnapStream recording.³⁰³

While the applications presented so far focus on both the viewing and the recording of programmes, a piece of software exists, which almost only focuses on making the viewing of television content on computers a pleasurable experience. This piece of software, DScaler³⁰⁴, excels in being able to scale and de-interlace the television programmes³⁰⁵. While the scaling – i.e. making a picture of one resolution fit another resolution – is a quite trivial matter, de-interlacing is not. If this is not done, the contours of the image will have jagged edges, because the progressive display does not show the half-frames of the interlaced signal the way it is meant to. The application must blend the interlaced fields together for viewing on the computers progressive-scan display. To achieve this, odd and even scanlines must be interwoven in a way that provides a natural looking picture.

A way to avoid interlacing – and thus an alternative to de-interlacing – is to reduce the image to half its original size. Hereby all odd (or all even) scanlines are discarded, leaving the viewer with an image suitable for viewing on progressive scan displays. The very considerable drawback of this method is, that the viewer only gets half of the original information.

³⁰³ (<http://www.interrorem.com/labrat/images/digiguide-plugin3.gif> - link active per 020606)

³⁰⁴ (<http://www.dscaler.org/> - link active per 020606)

³⁰⁵ Later versions of DScaler have a built-in capture facility, but this is an experimental version.



Figure 30: Screen segments before and after application of DScaler's 3/2 pulldown algorithm.³⁰⁶

DScaler provides a wide array of de-interlacing algorithms, each suited for a particular form of content (movies, sports etc.), some designed for powerful computers, some for those with less CPU power. The ability of the computer's calculating power in combination with the appropriate software to solve the problem of interlacing is an important function, which aids the particular convergence opportunity of television viewing and recording on computers. De-interlacing algorithms (often borrowed from DScaler) also find use in other pieces of TV-tuner software. SnapStream and Hauppauge's tuner software accompanying their tuner cards, for example, incorporates the de-interlacing filters of DScaler.

The applications presented above are all designed for use with analog TV tuner cards. For the digital tuner cards, similar software is available. Besides the software developed by tuner card manufacturers, impressive pieces of 3rd party software are also appearing. An example is WinDVB Live developed by the German company ODSOft³⁰⁷. Apart from supporting most available cable and satellite DVB tuner cards, it adds advanced features such as scheduled recording and control of motorized satellite dish.

All in all, the wide array of TV tuner applications gives the computer not only the same input abilities as a traditional TV/VCR/Set-top-box combo, but adds further functionality, made possible by the distributed calculating power and internet access of the computers. With software adding services beyond what is available from the television sector, TVPC viewers can have access to at least the same amount of information as the TV user.

³⁰⁶ (<http://www.dscaler.org/screenshots/index.htm> - link active per 020606)

³⁰⁷ (<http://www.odsoft.de/> - link active per 020606)

8.2.2. Output capabilities

The *output capabilities* depend on the appliances means of conveying the content to the users by sensory stimulation. Here, the capability of displaying *picture* and *sound* are those traditionally undertaken by the television, and as such they are subject to investigation when examining the computer's suitability for conveying television content. Sensory inputs beyond the well-known forms of sound and vision are further described in the "The Modality Case Study", which has particular emphasis on the computer's ability to provide high quality sensory stimulation.

8.2.2.1. Sound

The computer's ability of sound output has increased steadily over the last decade. As presented in the table on page 155, the computer is able to output virtually whatever number of sound channels the TV viewer could possibly desire. The sound output of the computer is usually delivered by a so called sound card, which is an electronic circuit board that – like the TV tuner card – goes into one of the motherboards PCI slots. These cards usually have mini-jack connectors for stereo sound, and often analog mini-jack connectors for right and left rear, subwoofer and centre front speaker as well. Thus fully equipped, the sound card can deliver 5.1 audio directly to any common amplifier/speaker set.

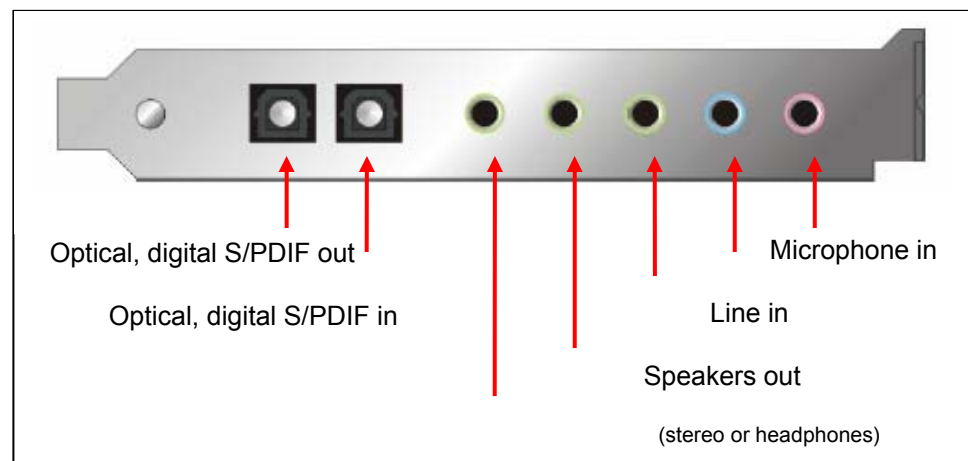


Figure 31: Digital and analog connectors on a modern sound card.

Many computer applications are designed for surround-like sound with four speakers only. In case the card has outputs for 5.1 analog (i.e. three stereo connectors), the user can choose to output to four speakers only.

In addition to the analog outputs, many modern sound cards are equipped with digital in- and outputs. These can be used for connecting to an external receiver or amplifier

with a built-in surround sound decoder. This, however is not without it's own problems. With the hardware-based decoding of surround information taking place in the surround amplifiers of the Hi-Fi world, any new standards stand a slim chance of being decoded. With the computer and its sound card having software to take care of decoding of the surround signal, it would probably be a question of time, before a program is available that enables output from the analog mini-jack connectors.

An example of this is the DTS³⁰⁸ system mentioned on page 152. This sound format can often be found on DVDs alongside the poorer quality Dolby Digital track. With a television sector setup of appliances, the user would need a DTS-capable surround receiver. If his receiver is not DTS-capable, he would have to settle for Dolby Digital or purchase a new receiver. The computer user would be able to achieve DTS sound with a recent DTS capable DVD software player, e.g. WinDVD or PowerDVD, and have his 5.1 channel sound card output the analog streams. Instead of having to spend a large amount on a new piece of hardware, he would have to only purchase a cheap software update.

There seems to be general agreement among enthusiasts, that the external decoders, one of which is shown in Figure 32, do a better job of decoding the signal. However, with the increasing processing power of computers, it is likely that this difference will diminish in the future.



Figure 32: Onkyo multi-standard surround receiver.

No matter which solution is chosen – be it internal or external sound decoding, two, four or 5.1 speakers, the TVPC user has the benefit of the same facilities as the user choosing his appliances from the television sector (to which the Hi-Fi sector is regarded as belonging). Though perhaps left with a marginally poorer sound quality, he will in turn have the benefit of cheaper updates to whatever new standards might be introduced.

³⁰⁸ Digital Theater Systems, Inc.

8.2.2.2. Video

Over the last decade, the computers output facilities have improved significantly, from having a 15 pin VGA connector³⁰⁹ only, to being able to also output a digital signal as well as a signal that can be understood by a television set.



Figure 33: Modern graphics card with VGA out, TV out, DVI out and connector for shutter glasses³¹⁰.

These capabilities are taken care of by the graphics card³¹¹. It is a circuit board resembling the sound and TV tuner cards presented earlier. An important exception is, that graphics cards use a special dedicated bus, the AGP bus, on the motherboard – instead of the PCI bus used by the other cards. Earlier, graphics cards were also PCI cards, but during the recent years, the increased graphics requirements have lead to the development of the more bandwidth-capable AGP bus.

While still being primarily geared towards outputting progressive scan signals for computer monitors, many newer graphics cards have on-board composite and S-Video outputs, making it possible to connect the computer to a television set for viewing. This connection is not without problems, however, as the resolution of most television sets are considerably lower than that of computer monitors. The result is a grainy and unsharp picture.

For a computer to properly undertake the same functions as a TV set and VCR, it is necessary to somehow be able to output the graphics to a larger display area than that of the traditional computer monitor. The reason is, that TV is consumed in considerably different usage scenarios than a computer traditionally is used. While the personal computer has been placed on a desk and used by individuals, TV is often viewed by groups from sofas and armchairs. The distance to the screen is much larger, which is why the screen itself must be correspondingly large. A typical analog cathode ray tube (CRT) television set is around 28 to 30 inches measured diagonally, while a

³⁰⁹ There were numerous monitor connectors before the one usually referred to as “VGA”, but they are not relevant here, as they aren’t in use any longer.

³¹⁰ This card is the ASUS V8460Ultra/Deluxe. (online reference: <http://usa.asus.com/vga/agpv8460/overview.htm#> - link active per 020611)

³¹¹ a.k.a. Video adapter, graphics board, VGA card etc.

CRT computer monitor typically is 17 inches. Large presentation monitors for computers exist, but they are prohibitively expensive - and very bulky.

Fortunately, alternatives to CRT TV sets and computer monitors exist. Lately, large flat plasma or LCD screens – often around 40 inches – have been introduced. They are typically equipped with connectors for computers as well as antenna signals, thus acting as stand-alone TV sets. These big displays are well suited for TVPCs, but the high price makes it an option only to those who have much money to spend on equipment.

The most viable alternative for a TVPC user is to connect a *projector* to the computer. Though not exactly cheap, projectors often cost less than half the price of a large flat plasma display, and it furthermore has the capability of generating a very large image – over 100 inches in diagonal, if one should so desire.

Until the early 1990s, projectors were large non-portable devices using analog CRT technology. With the emergence of the laptop computer, the advances in LCD technology lead to the development of smaller, portable projectors, often used for presentations in combination with a laptop computer. Since Texas Instruments launched the DLP micromirror technology in the late 1990s, the LCD projectors are not the only type of portable projectors available. These two generic types resemble one another in their physical form, but use quite different technologies to generate the image. One important thing they do, however, have in common: They both use a fixed resolution, their LCD panes or DLP chips being equipped with a finite number of pixels. Many of them have built-in scalers, making it possible for the projector to translate the input resolution into what is known as its *native resolution*³¹², but quality always suffers, leaving the users with a somewhat fuzzier picture than would have been the case if the projector had been fed its native resolution. The older analog CRT projectors are – like the CRT computer monitor – able to accept a wide array of resolutions, and is furthermore better suited for displaying an interlaced signal than the newer projectors, which to a large extent is based on digital technology.

Whereas interlace scanning is analog friendly, progressive scanning is digital friendly.

Quote box 9: The connection between analog/digital and interlaced/progressive³¹³.

³¹² The “native resolution” is the resolution on the LCD panel or DLP chip – e.g. 800x600. An alternative to scaling is keeping the image at its native resolution, discarding the projectors unused pixels, hereby not utilizing its full resolution capability.

³¹³ Smith.

With the market's move away from CRT projectors – unless for very specific purposes – to LCD and DLP projectors, much of the signal processing taking place to generate a picture became digital. However, until the emergence of the DVI connector as the de facto standard, the only viable way of getting the picture from the computer to the screen was converging the signal to analog form before sending it out through the graphic card's VGA connector, and then again, inside the projector, to convert it back to digital form so that the image could be generated by the projector's hardware. This conversion back and forth between analog and digital reduces image quality, which is why the coming of a digital interconnection, allowing the video signal to remain digital until appearing as coloured light, is a great step towards improved picture quality.

One of the important potential obstacles in using projectors for TV viewing via computers has to do with the properties of the image. One of the North American HDTV formats, 1920x1080 interlaced is ill suited for display on today's projectors. Firstly, there is the issue of interlaced vs. progressive scan, where de-interlacing is necessary in order to achieve an acceptable viewing quality. As earlier mentioned, this is easily achieved, but the picture quality would have been better with a natively progressive signal. Secondly, none of today's consumer projectors are able to accommodate the high resolution of this format, as the most widespread native resolution of LCD and DLP projectors today is 1024x768 (XGA). Projector resolution has increased over the years from 640x480 (VGA) over 800x600 (SVGA) to today's resolution, so it is likely that future projectors will be able to display the highest HDTV resolution, but they have not yet been announced.

The next logical step in projector resolution is somewhat problematic. The computer industry's de facto resolution SXGA is 1280x1024, which, interestingly enough, does *not* conform with the 4:3 aspect ratio of every other modern computer resolution. SXGA, by contrast, results in a 5:4 aspect ratio³¹⁴. This poses no problem on a CRT monitor, where the picture can be stretched, either via the monitor's adjustment buttons or by its advanced automatic geometry adjustments. When developing DLP projectors, by contrast, this is a considerable problem, because the digital micromirror devices (the DMDs – i.e. the chips generating the image) are limited to square pixels³¹⁵. Thus, in order to get the correct 4:3 aspect ratio, it would be necessary to apply lenses to the projector, stretching the image horizontally. This would be an expensive solution, which might be avoided by jumping directly to a resolution of 1600x1200 (UXGA), once the DMDs of this resolution have been developed.

³¹⁴ It has not been possible to find a well-founded explanation of this odd resolution. One suggestion found in a Usenet discussion is, that, in the 1980s, it "...came out of document imaging, where vertically-oriented pages meant that portrait or square image formats were a good idea... ...and 1280x1024 has been with us ever since." The source is Myers.

³¹⁵ Gove.

Compared to the issues of viewing the highest HDTV resolutions on today's 4:3 projectors, the DVB standard fits the projectors much better. Having 576 visible lines in 16:9 aspect ratio, equalling a square pixel resolution of 1024x576, the picture fits today's projectors well. The viewer will have to accept black areas at the top and/or the bottom of the screen, but these might conveniently be used for clickable buttons and sliders controlling brightness and contrast, sound volume and balance and other settings, which it can be relevant to adjust while viewing³¹⁶.

An issue which might make the whole discussion on how to fit digital television onto 4:3 DLP and LCD projectors is the fact, that projector manufacturers are introducing 16:9 projectors, suited for viewing of the modern digital widescreen video formats. This in turn raises the question of whether the computer industry will move towards 16:9 aspect ratio on computer screens. Such monitors have been introduced to the market, but it is still too early to assess their possible impact.

To conclude the discussion of appropriate display devices, it is likely, that the projector will play an important role in the convergence between TV sets and personal computers. Though a number of problems exist in the field of interlacing resolution and aspect ratio, the compact portable projectors stand a good chance of being put to use when computers assume the role of television appliances in television-like usage scenarios. This is especially true in Europe, where the limited resolution of DVB fits the current projectors well. No matter which display device is chosen, the computer is still able to output to every imaginable household TV set, so even if investment in advanced display devices might discourage users, the flexibility of the TVPC over traditional TV appliances can be enjoyed in conjunction with existing TVs.

8.2.3. Control capabilities

Control capabilities have to do with the way, the user interacts with the appliance. On TV sets, a *remote control* is traditionally used for switching the appliance on and off, selecting channels and adjusting sound and picture properties. This is a simple way of interaction easily undertaken from an armchair. By contrast, a computer is normally fitted with a *keyboard* many times the size of a remote control, plus a *mouse*, usually needing a smooth and level mouse pad in order to function. This project does not go deeply into the usage scenarios and habits of end users, but it is obvious that a computer requires another physical setting - at least for purposes demanding a high degree of interaction - than a TV set does.

³¹⁶ Using the black area for sound and picture control is this author's own suggestion of how to best make use of the wasted picture area. No actual implementation of this idea has been observed so far.

The recent availability of cordless keyboards and computer mice has made the situation somewhat easier. Without cables, the control capabilities can be moved to the viewing position, where they are within reach in case of sound adjustment, channel switching etc. Most of these functions can be done with a mouse (or an alternative pointing device – e.g. a trackball), so in most cases, the user can do away with the bulky computer keyboard³¹⁷. Recent so called optical mice makes the use even easier: here, the need for a mouse pad or a clean table surface is eliminated, as the user can move the mouse around on the fabric of a sofa or the leg of his trousers.

Apart from these proven ways of controlling a TVPC, a number of novel innovations have been introduced, giving the user simplicity of control similar to traditional infrared remote controls – and in other cases adding remote control functionality way beyond what is known from today's television appliances.

Among these, the more conservative approach is fitting the computer with an infrared (IR) receiver – a fairly cheap and common component that fits into the serial or USB port. By installing an appropriate piece of software³¹⁸, the computer can be made to interpret any IR control signal sent to it from any household remote control. Some configuration of the IR commands and their associated actions on the computer is necessary, but once this is done, the TVPC can be controlled with the same ease as a television set.

Building upon such systems, advanced applications can be installed on a PDA³¹⁹, which then can be used for remote controlling the computer. Equipped with a wireless LAN card, the PDA can send radio-based commands to the computer. The “line of sight” that is a precondition for functioning IR, is no longer necessary. The user will not have to point the remote in any particular direction – the TVPC can even be located in another room. This, however, is not the only benefit of such a remote control system. Because the PDAs have a built-in display, often in considerable resolution and with colours, the physical buttons are not necessary. The user can press various icons with the PDA's stylus, and bring up a number of different screens for controlling particular aspects (such as recording, picture settings and sound) of the TVPC.

³¹⁷ The earlier described PCTV software, ShowShifter, has a built-in keypad which can be made to appear on the screen. Here, users can point and click at numbers and letters, effectively substituting the physical keyboard for minor operations such as typing the name of a movie to be recorded.

³¹⁸ E.g. Girder (www.girder.nl).

³¹⁹ A PDA is a handheld computer, as e.g. the Palm Pilot or IPaq.



Figure 34: Screenshots from NetRemote – TVPC control software for PDAs³²⁰.

Such software is a very recent phenomenon, and there are no signs, that it is being used outside of groups of very computer-literate enthusiasts. Still, the existence of such products makes the potential usability of the computer as a TV appliance very high. One of the potential stumbling blocks, however, is the many different applications being developed for the various functions of the PCTV. This makes coordination a crucial issue, if a future of seamless interoperability between components is to become a reality.

8.2.4. Storage capabilities

With the coming of the VCR in the 1970s, the television set became able to display not only broadcasts, but also content stored on video tapes. Thus, *storage capabilities* are an important aspect of the computer in its role as a TV type appliance. For a TVPC to properly assume the role of traditional TV appliances, it must be able to not only play the media of the television sector, but also to record programmes.

While numerous pieces of DVD-player software exist for playing DVDs on computers the actual capturing and encoding is taken care of by the various types of TV tuner software described earlier, but a medium on which to store the recorded content for archival and later viewing is also necessary. Compared to the few different single-purpose storage media of the television sector, the computer sector offers a wide variety of options.

³²⁰ Online reference: <http://www.webwingnut.org/NetRemote/shots.html> - link active per 020612.

For a storage medium to be suited for TVPCs, there is a number of requirements it must fulfil:

- It should be cheap – preferably cheaper per recorded unit of time than traditional video tapes.
- It should be able to let the content be streamed – i.e. to play the recorded content before the entire amount of data has been transmitted.
- It should be easy to operate.

8.2.4.1. Recordable CDs and DVDs

Considering these three requirements, the recordable CD emerges as a good candidate for a suitable TVPC storage medium. It is considerably cheaper per unit of storage capacity than hard drives, but has one important limitation: its size is somewhat small.

If a user desiring functionality similar to that of a traditional VCR would like to save video files on CD-ROMs, there is an upper limit to the quality of files. The max size of CD-ROMs is 700 MB. One might want to use one's computer as a video recorder – and use CD-ROMs as the equivalent of video tapes. In this case, one would have to accept, that – with the compression algorithms of today – only a certain level of image and sound quality can be obtained. Future compression algorithms might improve the quality, but at present, the size of CD-ROMs – the cheapest storage medium – poses an obstacle to the use of computers in the domain of television sets and video recorders.

Other storage medium standards than the CD-ROM are available. As the CD-ROM, they are able to hold digital video files. Some are much larger in capacity than CD-ROMs (for example the DVD holds almost ten times the amount of information). But unfortunately, the price per unit³²¹ of storage is today way higher on the alternative storage media – and the CD-ROM with its price as low as \$ 0.25 per disc remains therefore a good candidate for the future equivalent of the VHS video tape.

Recently, different forms of recordable DVDs have been introduced, which could provide a suitable alternative to recordable CDs. The DVDs typically hold around 5 GB of data, so the limitations in quality posed by the 700 MB limit of CDs is not an issue here.

While there is only one standard for pre-recorded DVDs, the market of recordable DVDs is troubled by the existence of a number of mutually more or less incompatible

³²¹ There is one exception to this: Digital tapes such as Travan or DAT are in the same price range per unit of information as CDs, but firstly, the drives are rather expensive and second, streaming a file from tape is not very straightforward on a computer. The tape is first and foremost a *backup medium*.

standards. The first standard, DVD-R (a once-recordable disc), was developed by the industry consortium, DVD forum. This (together with the less adopted DVD+R format) is the only format, which can be recorded only once. The formats that can be re-recorded come in three flavours:

- DVD-RAM: The oldest among these formats, fully sanctioned by the DVD Forum. This format is given little chance of surviving due to its complex operation.
- DVD-RW: A more recent, easier to operate format than DVD-RAM, also sanctioned by the DVD Forum.
- DVD+RW: An alternative standard to DVD-RW, developed by the rival consortium DVD+RW Alliance. This format is not sanctioned by DVD Forum, though many DVD+RW Alliance members are members of both consortia.

If the agreement upon one particular standard is seen as desirable, the market situation of recordable DVDs is highly unfortunate. A potential buyer will have to accept the considerable risk, that his chosen format will become obsolete. This scenario serves to prove, that while consortium standardisation might be fast compared to the processes of the older SDOs and RSOs, the process of market selection while formats are battling it out can be a lengthy process, leaving large user groups with obsolete equipment. Furthermore, as marketing and strategic manoeuvring becomes increasingly crucial to the outcome of the battle, there is no guarantee that the winning standard will be the technically best one.

To make matters even worse for those, who are in favour of the convergence between TV and computers, there are efforts to make the two main combatants, DVD-RW and DVD+RW co-exist side by side. Sony, who developed DVD+RW together with Hewlett-Packard, Thomson, Mitsubishi, Yamaha, Ricoh and Philips, have abandoned the DVD+RW format for use on computers in favour of rival standard DVD-RW³²². Sony now aims at promoting DVD+RW for use on TV-appliances, thus stimulating the divide between the formats used in the two sectors.

According to Teece and mentioned on page 81, competition on price is most pronounced once a common standard has been agreed upon. Nevertheless, in this pre-paradigmatic phase of multiple standards, prices are dropping (RiTek³²³ – a disk manufacturer – expects prices to drop further during 2002: DVD-Rs from \$8 to \$5, DVD-RW from \$13 to \$10 and DVD+RW from \$15 to \$12). This is a predictable outcome of the growth of a hardware/software system, as pointed out by Katz and

³²² Williams, 2001.

³²³ Shim, January 11th, 2002. It should be noted, that DVD-R media are available considerably cheaper at the time of writing, but the quote is included to illustrate the industry's expectations of falling prices.

Shapiro on page 76: As a hardware/software system gets bigger, indirect externalities come about in the form of lower prices. If this development continues – and is not stopped by taxes³²⁴ on storage media – a recordable DVD could be the video storage medium of the future.

8.2.4.2. Hard Disks

The preceding paragraph have been focusing on removable storage media. These are traditionally the cheapest types, as only the actual substance carrying the data is removed. The hardware, which positions the disc or tape as well as the mechanisms reading the data remain in the computer. Only one instance of these pieces of hardware is necessary, no matter how many DVDs or CDs the user has. A DVD drive with recording capabilities might be costly, but the discs themselves are cheap.

A hard disk, by contrast, has no replaceable disks. It is an integrated unit, and if the user wants to add to his hard disk capacity, he will have to buy an additional disk. Hard disks, however, are also dropping in price, and they can in many cases be an easier and more future-proof alternative to the DVDs.

If, for example, comparing the alternatives of storing recorded programmes on hard disks vs. on DVD-Rs, the following comparison can illustrate the considerations:

- One 120 GB hard disk is available at \$ 144
- One DVD-R-capable drive is available at \$ 270
- DVD-R media are available at \$ 2.6 each

Hence, hard disk storage is the most cost-effective solution (viewed in price per storage unit) up until the total storage capacity of 420 GB, where the total price of three and a half hard disk as well as one DVD-R-drive plus 90 DVD-R discs (both yielding around 420 GB) both are approx. \$ 515.

If allocating 1.05 GB for a two hour movie, which is acceptable (at least VHS) quality, 420 GB will hold 400 two hour movies.

For comparison with the television sector, it takes 200 four-hour VHS cassette tapes to hold 400 two hour movies. Assuming a price at around \$3 per tape, this would cost \$ 600 in total – plus the price of the VCR itself and a considerable number of bookcases for the tapes.

Example box 4: Price comparison of storage media³²⁵.

³²⁴ Recently, European associations of intellectual property rights owners have succeeded in having taxes put on recordable CDs.

³²⁵ The prices of hard disks, DVD-R drive and DVD-R media are based on the lowest prices of selected consumer products from Pricegrabber at Tom's Hardware Page, per June 2002. (Pricegrabber can be found at <http://tomshardware.pricegrabber.com/> - link active per 020613).

Hard disk storage is particularly useful when the purpose of recording a programme is *time-shifting* rather than archival. If the programme is recorded because it is more convenient to view it at another time than when it was broadcast, there is no need for archiving the programme. By recording to hard disk only, the process of “burning” or recording to the DVD is avoided³²⁶.

No matter what storage medium is chosen for a TVPC, the important aspect is that computer’s storage media are not purpose specific. Virtually any form of computer storage medium is able to hold recorded television programmes. Files can be easily transferred from one computer to another, by transfer of the physical medium or via network, making the issue of settling on a common standard less crucial in the computer/networking sector than in the television sector.

8.2.5. Conclusion: Are TVPCs viable?

The above sections have described, how the whole range of functionalities of TVs, VCRs and set top boxes can be achieved on a PC. It has also been shown, how a TVPC adds even further to the usability, and has a built-in flexibility due to the relative ease and cheapness of software upgrades. This is especially the case when compared to the purchase of new hardware, which is often necessary in the television sector when new standards are introduced. Thus, the hardware-software dichotomy of computers proves to be a key strength in terms of flexibility.

What has not been described in depth, is the potential problems and frustrations facing a novice TVPC user. As is shown in the proof-of-concept prototype carried out in relation to this case, the complexity of the veritable patchwork of drivers, applications, codecs and interconnections of a TVPC might discourage many users, making them choose the proven and reliable television sector applications. They might well sacrifice the flexibility and quality for simplicity and peace of mind. On the other hand, computer literacy in Europe and North America is constantly increasing³²⁷, and an increasing number of hobbyists use the computer for editing home video and still pictures, for recording their own music and for other tasks, that demand a deeper knowledge of the workings of a modern computer.

When viewing the developments in hard- and especially software for TVPCs, it is clear that there is a trend towards easier installation, configuration and operation. Whether this trend continues with sufficient force to earn the TVPC a place in the

³²⁶ Here, it should be noted, that when recording on a TVPC with the intention of storage on an external medium such as DVD, one would almost always record to the hard disk first, and then transfer the video file to the external medium in a second step.

³²⁷ No actual evidence of the increase in computer literacy is identified. It is an assumption of this project, and is regarded by the author as a widely accepted fact.

future convergence landscape – or even to make the TVPC *the* future TV appliance - remains to be seen.

8.3. In-between Alternatives

The case of the TVPC focuses on the “pure” computer as a device on which to consume TV programmes. The focus has been one of little compromise: The device subject to analysis should be a computer; a so called *Wintel* – i.e. a computer using Windows³²⁸ operating system, an Intel CPU³²⁹, and the array of additional hardware, this type of computer can accommodate.

As has been shown, the capabilities of this type of computer are immense. As has also been suggested, they are difficult to install, configure and operate. But what if we could have the benefits of the computer without the complexity and instability? Will the future device for TV consumption be a convergence product offering the best of both worlds?

Lately, a number of products have arrived, using components of the computer/networking sector – i.e. hard disks, CPUs, memory chips and modems, but simplifying the operation and improving the design to give a less bulky and sleeker appearance. Many use hard disks for recording, and some use Linux operating systems. These appliances are often referred to as Digital Video Recorders (DVRs) or Personal Video Recorders (PVRs). The following sections describe a number of these products.

8.3.1.1. TiVo and ReplayTV

Both launched in year 2000, two similar DVRs pioneered the market for computer technology based digital video recorders. Offering similar features, Tivo and ReplayTV are natural competitors for the same market segment. Both have an appearance similar to that of a VCR or a satellite set top box. Both use computer hard disks for storing video. Both offer an electronic program guide, which makes for easy one-click scheduling of recordings. As the feature that most clearly gives them an edge over old fashioned VCRs, they both offer time-shifting, effectively giving the user an opportunity to pause a live broadcast and then resume it shortly after – even before the program is over, having the DVR record while simultaneously playing what is already recorded.

³²⁸ A rival operating system, Linux, also has applications giving the computer TV functionality, but the innovations are far between compared to those taking place within Windows.

³²⁹ When the term “Wintel” was conceived, Intel had a monopoly on CPUs for desktop computers. Later, AMD has risen as a serious challenger, so the idea of an Intel CPU in a Wintel computer should no longer be taken literally. Another term useful to identify the type of computer subject to analysis would be “PC”, as opposed to Macintosh or Silicon Graphics. Unfortunately, this concept is even less precise than Wintel, so it will not be used.



Figure 35: SONICblue ReplayTV 4500³³⁰.

There are a number of insignificant differences – most noticeably the operating systems used. While TiVo uses a variant of Linux, ReplayTV uses a less known OS called VxWorks. It is fair to say, that ReplayTV, having a VGA connector (complementing the usual set of composite and S-Video outputs) to which a projector or computer monitor can be connected, is marginally closer to being a computer than TiVo.

One important feature, which they –compared to traditional VCRs - do not have, is portability. There is no external medium in these DVRs, and as both use proprietary forms of data storage³³¹ the only way one can transfer the programmes to a computer is by removing the hard disk, install it in a computer and transfer the file using 3rd party software. This lack of portability has an interesting effect on the standardisation issues concerning these two particular DVRs. As the exchange of recorded programs thus is of little importance to the users, these products are components in hardware/software systems rather than parts of communication networks – therefore, interoperability is not a particularly important issue, why a standards war like the one which took place between VCR formats Betamax and VHS is less likely.

Though reportedly easy to operate, these two products are not particularly flexible. Without the option of portability and external storage, the DVRs are limited to function as time-shifting devices. Furthermore, none of them are HDTV-capable³³², which is a considerable drawback, leading to a possible future mass of obsolete non-upgradeable hardware.

8.3.1.2. Microsoft UltimateTV and Xbox

Microsoft, the company behind the most widespread computer operating system, Windows, has recently moved into the hardware area. With the development of UltimateTV, a device resembling TiVo and ReplayTV, equipped with a slimmed

³³⁰ Online reference: http://www.replaytv.com/video/replaytv/replaytv_4000_matrix.asp - link active per 020617)

³³¹ Yost & Gehman, 2001, p.10.

³³² Explained at online references: <http://www.sonicblue.com/support/replaytv/4000generalfaq.asp> and http://www.tivo.com/flash.asp?page=discover_faq - links active per 020617.

down version of Windows2000, Microsoft offered a competitor to these two other DVRs. The product was however discontinued, and Microsoft is expected to add television viewing and recording functionality to its gaming console, the Xbox³³³. By summer 2002, no TV tuner module is available for the Xbox, and the playing of DVDs is only possible with the addition of a special adapter. Today's box is thus far from being a serious contender to the title as DVR of the future.

An interesting feature is, that the Xbox has no VGA output – instead relying on output to traditional television sets, plus – with an extra adapter – HDTV in the 480p, 720p or 1080i formats³³⁴. This can be seen as a move away from the computer/networking sector and into the television sector. Though being based on computer hardware, the operating system of the Xbox is incompatible with the Microsoft operating systems for desktop computers, meaning that it is impossible to run software for “normal” windows PCs on the Xbox and vice versa.

Microsoft's incentive to this deliberate lack of interoperability is unclear. The Microsoft OS equipped PC is widely used for gaming, and Microsoft have a considerable share of the market for computer games. A suggestion as to why a dedicated gaming box is developed could be that it gives Microsoft control of the hardware instead of software only – perhaps integrating television, word processing and other functionalities later, and thus making the windows computer proprietary.

Such a development would stimulate a tendency towards more seldom – but larger – leaps in innovation. If the computer of tomorrow relies on TV sets to display picture and sound, the inherent flexibility of the computer will be lost. It is a phenomenon which can be observed in the market for gaming consoles, where companies such as Nintendo, Sega and Sony launch their successive generations of improved consoles – which by the way also have begun to include functionalities such as DVD-playing³³⁵.

8.3.1.3. Nokia Mediaterminal

Whereas the previously presented DVRs are geared towards the U.S. market, a promising DVR was developed by Nokia, who kept the appliance very much within the paradigm of computer/networking. Based on a Linux operating system, with and Intel Celeron CPU, traditional hard disk etc, the Nokia Mediaterminal was basically a computer in a compact cabinet. It appears to be discontinued per May 2002³³⁶, only one and a half year after its release in 2000, but no explanation has been given from Nokia.

³³³ Shim, January 22nd, 2002.

³³⁴ The Xbox website.

³³⁵ In spite of the DVD-playing ability, the dedicated gaming console have no recording or tuning capabilities, and their potential will not be explored further here.

³³⁶ Ryvarden, 2002.



Figure 36: The Linux-based Nokia Mediaterminal³³⁷.

The Mediaterminal was based on computer parts to an even larger extent than TiVo and ReplayTV, and had a Linux operating system, which to a large extent was developed by the open source community³³⁸. With the great flexibility of the configuration and its elaborate remote control featuring a full keyboard, it was capable of practically anything a traditional Linux desktop computer could do. Being DVB and MHP (see below) compliant, it was a good bid for an effective convergence product on the European market.

8.3.1.4. MHP

The Multimedia Home Platform is an initiative³³⁹ started by the DVB consortium in 1997³⁴⁰. Primarily based on Sun Microsystems' JAVA, MHP is designed to be *the* standard for set top boxes, doing away with the proprietary systems as MediaHighway (used by Canal Digital) and OpenTV (used by Viasat).

Approved by ETSI by 2001³⁴¹, the standard seems to have good backing as the future European API³⁴². Per 2001, the similar initiative covering the Nordic countries, NorDig, committed itself to adopting the MHP standard at the latest in 2005³⁴³.

The standardisation process of MHP is not progressing smoothly. Some members of the organisation have been accused of trying to sabotage the standardisation process. This is especially the case for those who already are promoting their own proprietary API, which gives them control of the hardware and the encryption process among

³³⁷ Picture from <http://www.linuxdevices.com/articles/AT4370516520.html>

³³⁸ Two major community developing software for the Mediaterminal is ostdev.org.

³³⁹ MHP describes itself as a "consensus-based organisation". There is no indication, that it differs from the common concept of a *consortium*.

³⁴⁰ Evain, 2000.

³⁴¹ The MHP website.

³⁴² API: Application Programming Interface.

³⁴³ The NorDig website 2001.

other aspects. Lately, Modern Times Group, the conglomerate behind Viasat's TV3 has been accused of sabotaging the NorDig standard, and has been in risk of losing its rights to distributing television in Sweden³⁴⁴.

Such problems are not at all surprising, as consortia often have been accused of being inefficient because a number of their members actually participate in order to sabotage the new standard, or – at best – promote their own technologies.

8.3.2. Conclusion: Does the future belong to the DVR?

The last couple of years have shown a multitude of convergence products using computer technology to do the tasks of traditional television sector appliances. With varying degrees of resemblance to “real” computers, they have offered a number of improvements over analog, tape-based VCRs.

With some products still existing on the market, others having vanished, and the de facto and de jure standard still not quite decided, it is a market, the future of which is difficult to foresee. There is no doubt that the simplicity, ease of installation and operation is a considerable asset compared to the TVPC. But while new DVRs are introduced, others disappear and standards are discussed, the TVPC continues its development.

8.4. Conclusion

This chapter has analysed the capabilities and potential of computers in use as TV appliances. The TVPC shows great potential as an alternative to the traditional television appliances, either in the form of “conventional” computers equipped with the appropriate hard- and software, or as specialized DVRs, using computer hardware, but without the need for installation and configuration on behalf of the user.

Compared to the traditional television set, the TVPC is expensive, but versatile. It is able to process and display all the information and communication forms typical to the television sector as described in the taxonomy on page 121. These communication forms are all real-time one-to-many forms of communication. The moving pictures and sound can be displayed in a quality similar to that of the traditional TV appliances, while the text-based information, teletext, is much more usable on a TVPC, which is able to store an almost infinite number of pages for easy and immediate access and present them in more readable ways than on a TV set.

Compared to the development of DVRs, the TVPC progresses continuously due to the fact that development of the underlying hardware (processors, graphics adapters, storage media, etc.) are developed for a multitude of purposes such as word

³⁴⁴ Ingeniøren, 2001.

processing, gaming and communication. The hardware for TVPCs do not depend on agreement among developers, and the software developers can concentrate on developing their applications, integrating their software with complementary services such as online TV guides, and having different solutions tested by the market's selection. All without the gamble involved in having to develop a particular piece of hardware for the services offered, and with the flexibility coming from allowing new and improved versions to be easily downloaded via the Internet. The DVR undoubtedly has an edge over the TVPC in terms of ease of installation, configuration and operation. However, the DVR market is plagued by a number of appearing and vanishing standards, while the TVPC software market is able to continue a steady development and refinement of its applications. Therefore, there is no clear indication of the outcome of the DVR vs. TVPC competition.

8.4.1. Reverse Salients and Scientific Advances

One of the most easily recognized reverse salients³⁴⁵ of the television sector is interactivity. Here, the computer, continuously developed with the aspect of user interaction in mind, has a significant advantage. The TVPC is capable of incorporating a wide variety of complementary services, partly due to its large degree of user control, partly because the communication infrastructure normally used with computers – i.e. the Internet and local area networks – are inherently bi-directional, offering a return path for the commands of the viewer.

For a long period of time, the low resolution and poor sound reproduction has been another candidate as a reverse salient. With the specification of and ongoing transition to new digital TV systems, this will hardly be the case in the future. Even though the computer offers much higher resolutions than any digital TV standard contains, the content³⁴⁶ necessary in order to fully make use of these capabilities does not, and might not exist in the foreseeable future, rendering the upper margin of the computer's envelope of performance useless.

8.4.2. Standardisation processes

It is characteristic of the television sector, that de jure standardisation is the typical way that standards are established. With the sector's many involved global, regional and national standardisation authorities, much discussion and development is often necessary before a standard is agreed upon. Furthermore, the standardisation processes are characterised by the involvement of many private companies, who have clear economic incentive in preserving a system, which might be suboptimal to the public, but is beneficial to them.

³⁴⁵ I.e. areas, which lag behind the development of a certain system.

³⁴⁶ Such content could be for example movies in a resolution of 2048 x 1536.

In the computer/networking sector, standardisation is less regulated, and the SDOs, RSOs and NSOs characteristic of the television sector play lesser roles in the development of computer hard- and software and the standardisation of Internet communication. Also, because the media and infrastructures of the computer/networking sector are able to support a wide variety of information, many competing solutions to a particular problem can co-exist without the need for a speedy settlement on a common standard. This makes for a de facto standardisation environment with little emphasis on public-interest organisations, in favour of a market selection among the offered soft- and hardware. In some cases, this process can, however, be even lengthier than that of the large and well-established standardisation organisations. This is particularly the case with the future optical storage media, where multiple standards exist.

8.4.3. Installed Bases

The problems involved in standardisation in the television sector are to a large extent results of the nature of the installed base of appliances. With the little flexibility inherent in TV sets, VCRs and satellite tuners, frequent changes in resolution, refresh rate, scan method etc. will make the effective life cycle of appliances very short, often leaving many users stranded with unusable equipment. Considering the interest of these immense user groups, it is obviously necessary to wait implementing whatever innovations are introduced, until the necessary new investments of users are justified by the perceived value of the new system.

By contrast, the installed base of appliances in the computer/networking sector is inherently flexible, and new incremental improvements are introduced regularly. The computer/networking sector, with its more modular approach where individual components (graphics and sound cards, CPUs etc) are easily replaceable is thus more geared towards more frequent, but less radical innovations.

8.4.4. Flexibility

Though the TVPC case has demonstrated, that it is possible – via a mix-and-match approach – to achieve flexibility by far surpassing that of the television sector, there is still some rigidity remaining in the components. This is especially the case when dedicated chips are included in the components in order to compensate for lack of CPU power. As can be observed in the case of DVB tuner cards, the pure software-based cards are better suited for adapting new resolutions, scan methods and refresh rates in digital television.

The computer is only truly flexible when it is independent from such forms of dedicated hardware. When special purpose hardware such as MPEG2 decoder chips are used, changing standards is a problem. However, the current increase in CPU processing power suggests, that within the limits of currently proposed television

standards, CPU power alone (i.e. without the aid of dedicated hardware) is sufficient for handling the relevant qualities. Any audio or video standard, which can be decoded by software with the processing power of a household CPU³⁴⁷, can be replaced or improved without any particular disadvantage to the consumers. Often, downloading a new piece of media playing software – or in some cases just a codec – is sufficient to be able to benefit from a new and improved standard.

With software-based decoding, the computer/networking sector has the opportunity of a very high rate of innovation, as the switching costs of changing standards are negligible.

The flexibility of computers is particularly obvious in their ability to incorporate different video and audio codecs and use different media for storage of content. Hereby, the TVPC is a very adaptable device, capable of incorporating new soft- and hardware without major changes to the basic configuration. Furthermore, new services for TVPCs are easily introduced, as capability of using a new service often is a question of downloading the appropriate software. The television sector's appliances, with their purpose specific media and hardware based en- and decoding are less suited for rapidly changing standards.

8.4.5. Life cycles

The rapid changes of standards make the life cycles of computers shorter than that of television sector appliances. The big leaps in innovation, which are characteristic of the television sector, are not necessary in the computer/networking sector.

The way that equipment becomes obsolete is thus different among the sectors: Computer equipment is replaced not as much because it adheres to an old and abandoned standard, but rather because newer and more capable alternatives have become more attractive. The television sector's appliances, by contrast, remain relatively competitive *until* a new standard is introduced.

When postulating that the flexibility of computers makes their standards long lasting, it is surprising to observe that computer equipment is made obsolete more frequently than TV appliances.³⁴⁸ One could wonder why this is the case; if computers are so flexible, that they are able to easily incorporate new standards. The answer is, that computer users are not *forced* to replace their equipment in order to keep up with the latest in information and communication. The increase in quality, however, is so substantial, that it often makes the expense worthwhile.

³⁴⁷ Per June 2002, the latest desktop PC CPUs have frequencies of around 2000 MHz.

³⁴⁸ This can be seen from e.g. Figure 24: Innovations in resolution in the television and the computer/networking sectors.

The benefit of the frequent replacement is, that if new standards are introduced in the computer/networking sector, switching opportunities are more frequent. This to some extent contradicts the claim made here, that computers are able to cope with many new innovations through software updates. To make the message more obvious, one could say that *in the computer/networking sector, switching is a result of consumers' whims rather than necessity.*

8.4.6. Communication Networks and Hardware-Software systems

With DVRs lacking portability, these remain hardware-software systems. With the traditional tape-based VCRs as well as the TVPCs, an external storage medium is available. Hence, exchange of recorded material as well as purchase or rental of pre-recorded media is necessary. This to some extent gives the appliances the characteristics of communication networks, where the standard choice of other users become important to a network entrant due to the external effects of using the same standard as others.

A critical component of the TVPC is the external storage media. There is reason to believe, that – especially once a common standard for recordable DVDs has been agreed upon - prices will drop, as described on page 192.

8.4.7. Positive Feedback

If remaining hardware/software systems rather than turning into communication networks, the external effects and positive feed-back of TVPCs will remain limited, their primary effect being of a derived nature, influencing the price due to economies of scale as described in the theory chapter on page 76. When or if private support networks become important in relation to TVPCs, positive feedback will occur stronger, condensing the adoption around one or few hard- and software solutions.

8.4.8. Path Dependence

This chapter, as well as the “Signal, Interconnection and Content Standards” chapter (especially under the “Resolution and Scan Rate” header on page 138) accentuates the differences in the two sectors in fields such as scan method and aspect ratio. It seems to be widely agreed, that progressive scan and 16:9 aspect ratio for various reasons are the better choices. This raises the question of, whether these issues are cases of 3rd degree path-dependence as described by Liebowitz and Margolis.

For this to be the case, there has to be a chance to remedy a suboptimal choice – i.e. in this particular case to make a shift from 4:3 to 16:9 and from interlaced to progressive

scanning. This chance is clearly at hand with the shift from the old analogue system to the new digital one and the replacement of appliances induced by this shift.

In the case of aspect ratio, it is difficult to identify when the chance of remedy (if indeed there has ever been one) occurred. With the large installed base of not only 4:3 TV sets, but also virtually every computer monitor in 4:3, a considerable bulk of equipment would be made obsolete by such a change. This makes it fair to say, that no opportunity for remedy ever really occurred.

The case of interlaced vs. progressive scan seems a better candidate for 3rd degree path dependence. Here, a large number of progressive scan display devices exist in the computer/networking sector. With the new digital television standards incorporating progressive scan, the chance of abandoning interlaced scan altogether was perhaps existent when the standards were developed.

There are two likely explanations of why the suboptimal choice is not remedied. The first, coordination failure, might well apply to this situation, as we have three major areas, North America, Europe and Japan in a transition from analogue to digital television. This makes for a complex situation, difficult to manage and coordinate. The other explanation is however even more plausible: Certain of the parties involved in the standardisation process have an incentive to keep the older and less efficient standard. TV equipment manufacturers, for example, who are specialized in developing appliances for interlaced scan will be comparatively weaker within a TV standard only allowing progressive scan. A similar position can be expected from the movie industry as well as some broadcasters, as indicated on page 140.

8.4.9. Complementary Assets

One of the areas, where complementary assets have their most profound influence in this case, is the TV guides that are offered as part of the “package” of service of the various appliances and applications. In all three major distinguishable cases, the DVR, the TV set and the TVPC, the TV guides act as specialized assets as defined by Teece on page 78 f., as they are unilaterally dependant on the basic service: Television works without a TV guide, but a TV guide is not much use if there is no television.

There are, however, differences in the degree, to which the TV guides add value to the basic service. For the DVR, the TV guide also serves as the interface, from which one selects the programmes to be recorded. Therefore, they are highly integrated specialized assets of the DVRs, adding substantially to their value – to an extent where the programme guides and the DVR hardware almost are *co-specialized assets* – i.e. mutually interdependent assets.

In the cases of the traditional TV set, the dependency between the programmes and the teletext based programme guide is purely unilateral – the TV would work fine without it. It is, however, strictly related to – and controlled by – the particular TV channels.

On the TVPC, the Online TV guides are loosely connected specialized assets, when used to get an overview of the available programmes. When used in conjunction with TV tuner software such as ShowShifter or Snapstream described earlier, they assume the character of the TV guides of the PVRs, adding considerably to the utility of the software.

These tendencies of DVRs and to some extent TVPCs emphasize the importance of integration or at least interoperability of services. Complementary assets, when put to use as described here, can play important roles in adding value to the basic services or appliances. They might be controlled by the appliance manufacturer (as is the case for DVRs), or by 3rd party service providers (as is the case for TVPC tuner software). In the first case, the keyword is integration, but in the latter – the scenario which opens up for the choice between a variety of TV programme services, the crucial aspect is smooth interoperability between services, software and hardware.

8.4.10. The Promise of Interoperability

One of the promises of convergence identified in this work is interoperability. This means that the content of one sector – e.g. TV programmes – can be viewed on a device from another sector – in this case a computer. This also encompasses issues such as mixing the services and appliances of the two sectors, thus creating new opportunities for the viewer as well as the content and hardware provider.

The computer has proven able to fully function in the role of TV set and VCR. Due to the many software options available, the traditional content of the television sector can easily be viewed and recorded on a TVPC. Utilization of web-based services such as online TV guides is also possible³⁴⁹, adding capabilities not existing in traditional TV sets. New audio and video codecs make it possible to store programmes on recordable CDs, making storage cost considerably lower than that of traditional video tapes.

A well-equipped TVPC is also able to operate with the appliances of the television sector – most importantly TV sets and VCRs. The major reason for using appliances of the two sectors in combination is the small size of computer monitors, which makes them ill suited for a traditional television usage scenario. By using a traditional TV set to show the computer's picture, a reasonable display surface can be achieved. The drawbacks are, however, that no matter whether connection is done via composite, S-video or VGA, the poor resolution and refresh rate of most TVs act as the lowest

³⁴⁹ Other forms of “mixing of services” are analysed in the “The Hybrid Communication and Information Case Study”.

common denominator and results in a picture which does not at all utilize the quality potential of the computer.

Another reason for mixing appliances is to view or capture a videotape on a computer. This is made possible by the composite or S-video inputs available on many graphics cards. This is not necessary when viewing DVDs, as most computers have drives capable of playing this medium.

While the options of interoperability are many, some technical properties of the two systems do however pose a problem: The fact that the television sector introduces the 16:9 aspect ratio and maintains interlaced scan are obstacles to the interoperability and thus as factors hampering the convergence process. These obstacles can be overcome by tolerating – and perhaps in some way utilizing³⁵⁰ – black bars on the computer's display device as well as a marginal quality loss from de-interlacing processes.

The main problem of the TVPC is its price and complexity compared to TV sets. The latter might especially deter potential users from exploring this form of TV consumption, as it – in order to overcome the obstacles of e.g. interlacing – is necessary to be quite apt at configuring a computer.

While this chapter has focused on the potential of the computer for TV consumption, development going “the other way around” has also taken place. Some newer TVs have VGA inputs for displaying a computer's picture – a convergence phenomenon further blurring the border between a computer monitor and a television screen. Furthermore, set top boxes capable of undertaking some of the tasks of a computer (i.e. word processing and Internet browsing) have become available. Thus, the development is taking place in two directions, and the outcome might well be a device offering the low price and simplicity of TV appliances combined with the flexibility and quality of computers.

8.4.11. The Promise of Quality

Another of the promises of convergence is the ability of future appliances of displaying content of higher quality in terms of e.g. resolution and refresh rate. These are the so-called incremental improvements, which are different from the radical ones described in “The Modality Case Study”.

The TVPC has the capacity of displaying high quality audio and video – considerably higher than that offered by even the most advanced HDTV set. Unfortunately, this is of little use as long as the TV broadcasts do not utilize this capacity. With the low resolution of current analog and European digital television, the TVPC has much unexplored potential.

³⁵⁰ As mentioned on page 5.

The North American situation is considerably more favourable to the TVPC. Here, content with higher resolutions and refresh rates as well as progressive scan is more suited for being consumed on a computer. The investment and hassle of using a computer for TV consumption is thus justified to a greater extent than is the case with analog and European digital TV.

If the Internet is further developed, delivering high-capacity connections to private homes, a possibility of e.g. “Video on Demand” in whatever resolution and refresh rate the customer might desire, can be an alternative to the programmes delivered via the television infrastructure onto TV sets. The content is not yet available – most movie content on the Internet is of low quality due to bandwidth constraints, but there is no chicken-and-egg problem as such. Bandwidth to the homes has been continuously increasing over the last decade, and must be expected to continue to do so as consumer demand makes expansion of the infrastructure viable.

9. The Modality Case Study

Among the promises of convergence presented in this work, the *quality promise* is probably the easiest comprehensible. Television viewers have for decades been buying improved television sets with better picture tubes, and better speakers. Computer users have been used to a steady increase in picture resolution. These are, however *incremental* improvements, offering sensory input in familiar ways, just better.

This chapter is concerned with the more *radical* improvements. Examples are the switches to colour and stereo sound television or the introduction of four-speaker surround sound on computers. These innovations are fewer and further between than the incremental ones, but on the other hand bring about very noticeable improvements to the experience of TV viewing or computer usage. They alter the ways, in which the human senses are influenced and introduce new challenges to appliance manufacturers as well as content providers.

9.1. Introduction

To cover the ways, that human senses can be influenced, the term *modality* (as described on page 5) is used. There are five basic modes of influence: vision, hearing, smell, taste and feeling. Among these, the traditional means of conveying information in the television and computer/networking sectors have been through visual and auditive perception (through sight and hearing).

While visual information has been subject to few radical innovations, the number of sound channels in both sectors have increased considerably over the last decade, as has been described in the “Signal, Interconnection and Content Standards” chapter.

Other modes such as olfactory (through smell) and tactile (through the sense of feeling) are more exotic. Recently, force-feedback joysticks and steering wheels for computer games have provided tactile feedback to users, hereby adding to the realism of gaming. Olfactory input have only been attempted sporadically, for example by issuing cinema audience with scent impregnated paper, which should be rubbed during certain scenes, releasing various scents enhancing the movie experience. Recently, DigiScent, a scent-emitting computer peripheral has been developed³⁵¹, but has yet to find adoption among users.

The focus of this chapter, however, is the radical innovations in the field of *vision*. More precisely, the possibilities of adding stereoscopy (i.e. depth perception) to the visual content of the television and computer/networking sectors. This has been tried

³⁵¹ Platt, 1999.

before, in cinemas as well as television. Success has been limited, apart from a boom of stereoscopic Hollywood movies in the 1950's. Now, as computers are becoming increasingly flexible and powerful, actual working implementations of three-dimensional content can be observed. This chapter looks at the different forms of stereoscopy in the two sectors, and examines whether the computer/networking sector can provide a platform on which stereoscopy can thrive and develop further.

9.2. Stereoscopic methods

Attempts of adding depth to photographs have been carried out since the early days of photography in the 19th century. Moving pictures have likewise been subject to stereoscopic experiments from its early beginnings, with television broadcasts carried out since 1953³⁵², only to almost disappear once the initial fascination with stereoscopic vision had decreased.

9.2.1. Separation methods

Human depth perception is based on the slight differences in perspective between the images reaching the left respectively right eye. All methods of generating stereoscopic images are based on the principle of sending one specific image to the left eye of the viewer, and another (with the slightly different perspective) to the right eye³⁵³.

The simplest solution is to have separate display devices for each eye's picture. This is the principle behind the so called free-viewing technique known from side-by-side images of molecules in chemistry textbooks.

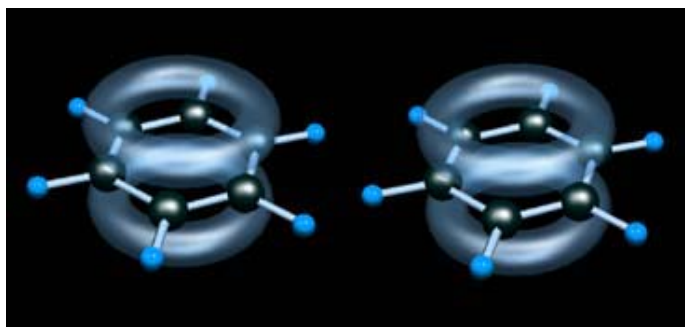


Figure 37: Parallel view representation of benzene molecule³⁵⁴.

³⁵² Starks.

³⁵³ Some alternative methods such as volumetric displays exist, but they are quite exotic and expensive, and will not be described here.

³⁵⁴ From the Gianni Maiani homepage: <http://web.infinito.it/utenti/g/gmaiani/Grafica-stereoscopia/stereogallery.html> - link active per 0203.

The same principle is used in head-mounted displays (HMDs), which contain a small screen for each eye. These methods are however not suitable for larger displays, as the distance between the two images must not exceed that of the human eyes for the stereo image to be properly perceived.

The methods in focus in this chapter are those, which use one display surface for both right and left eye's images. The main challenge is separating the images so that each image can be viewed by the eye intended – and *only* by that eye. Here, three different methods can be used.

- Separation by colour
- Separation by polarization
- Separation by time

Colour separation – often referred to as *anaglyph* – works by having the image coded in two near-complementary colours – one colour for the left eye and the other colour for the right (e.g. red and green). The viewer must wear glasses with lenses in the same colour. Hereby, the images are filtered, leaving only the red part of the image visible through the red glass and vice versa. This is the method used in most of the stereoscopic movies seen in cinema and television. The major drawback of this method is that it destroys colour information, which – considering the alternatives – makes this method inferior in viewing quality.



Figure 38: Red-cyan anaglyph glasses.

Another method also used by cinemas in the 1950s is to separate right and left eye's images by *polarization*. Here, it is necessary to project the image onto a special non-depolarising surface with two projectors. Fitting each projector with polarising filters in front of the lenses, polarising light in different directions, and issuing viewers with glasses where each eye's glass is polarised correspondingly, right and left eye's images can be separated. This method – though very efficient – is best suited for larger audiences, as the purchase and alignment of two projectors plus a non-depolarising projection screen is quite expensive.



Figure 39: Polarizing glasses.

The method perhaps best suited for consumption in a “family” or “private home” usage scenario (which is the scenario of main interest to this project) is to separate the left and right eye’s images over time, the so called *field-sequential* (also known as “page flipping”)- method. This means displaying them in a fast alternating sequence and blocking out the path of the right eye’s image to the left eye and vice versa by the use of so called shutter glasses with liquid crystal panels. This method is usable for projection as well as CRT monitors; though with the limitation that the display device should be capable of fast picture refresh rates – preferably above 100Hz. This is necessary in order to provide a smooth looking image without perceivable flickering. Though shutter glasses are more expensive than the polarised or colour coded glasses, both television sets and computers can be used for displaying stereoscopic content with this method, making it a good candidate for family use.



Figure 40: LCD shutter glasses.

A method of generating pseudo-stereoscopy, often confused with anaglyph, is the use of glasses with one dark glass and one clear one. This method is referred to as Pulfrich³⁵⁵, and works due to the fact that the human brain perceives images coming through the dark eyeglass as being delayed. Hereby, a movie sequence filmed with a moving camera will be seen as having depth, because those images perceived at the same time by the brain will have slightly different perspectives. This method only works with movies shot with a moving camera, and must be regarded rather as a curiosity than as a serious method of stereoscopy.

Among these methods, field-sequential displays in combination with LCD shutter glasses is a strong candidate as a future home use stereoscopic system, as it is considerably cheaper than systems using polarisation, and gives full colour representation, which the anaglyph systems do not. Therefore, this method is explored in the further sections of this chapter.

³⁵⁵ This method was used by Danmarks Radio for the Christmas series “Pyrus” in 2000.

9.2.2. Stereoscopic formats

Another important parameter when describing stereoscopic content is the *format*. This has to do with the way, that e.g. a movie is encoded. Most of these formats can not be viewed without additional hardware – usually a pair of shutter glasses plus in many cases a piece of video processing equipment decoding the content for presentation on the display device (this video processing equipment is often software based when a computer is used).



Figure 41: Above/below format.

The *above/below* format contains right and left eye's images on top of one another, squeezed in order to maintain aspect ratio. This format is used for viewing on a computer. A so-called sync doubler (hardware- or software based) is used to stretch the image and display the portions for left and right eye sequentially and in sync with a pair of shutter glasses.



Figure 42: Side-by-side format.

The *side-by-side* format resembles above/below, but has the images arranged beside one another. They can be squeezed as shown in the figure, or they can have natural relations between height and width (which leads to a very wide image) To view with shutter glasses on a computer, a dedicated piece of software is needed – taking care of displaying the correct images in sync with the shutter glasses. Alternatively, in the case of un-squeezed side-by-side format, the content can be free-viewed as well.



Figure 43: Interlaced format.

The interlaced format is the only among those mentioned which is suitable for viewing on a television set. It contains the right and left eye's images interwoven. This allows it to appear in field sequential fashion when an interlaced scan display device plays the odd and even fields (containing the right respectively left eye's picture) in sequence. It can also be viewed on a computer, either by the use of a hardware-based line blanker, or a piece of video playing software able to translate it to field sequential form.

There are a number of more exotic formats with little practical use, which will not be mentioned here. The possibility of a natively field sequential format should however be mentioned, as it seems the easiest way to store stereoscopic content, as no conversion would be necessary. This would, however, compress very badly when stored in digital form, and sync to an analog tape would be difficult. Finally, the right and left eye's pictures could be stored on each their own medium (or as separate files). Here, the problem is synchronising the images during playback, and the method is primarily used when processing raw footage.

9.3. Display Devices

As mentioned earlier, for a shutter glasses based stereoscopic system to work, the display device must be able to display images in rapid sequence to avoid visible flicker. Here, a number of differences in the display devices of the converging sectors of television and computer/networking have interesting implications for the usability of stereoscopy.

9.3.1. The Television Sector

Stereoscopic field-sequential videotapes have been available for television viewing with (often bundled) shutter glasses for years. They have, however, never achieved any wide adoption, which can be explained partly due to the necessary additional hardware purchase (shutter glasses and controller), partly to the almost inevitable flickering on traditional television sets.

Besides the quality-wise inferior anaglyph method, the preferred stereoscopic format for viewing on television appliances is interlaced, as it uses the scan method of most TV sets to alter between right and left eye's pictures.

Most TV sets are using 50 Hz (PAL) and 60 Hz (NTSC) refresh rates, meaning that each eye would get 25 or 30 images per second (depending on TV standard). Some flickering can be remedied, as pointed out by Michael Starks of 3DTV Corporation: “The 60Hz flicker can be virtually undetectable if the ambient light is low, monitor brightness is adjusted and images avoid large light areas.”³⁵⁶. Unfortunately, ambient light is not easily controllable in the average living room. The amount of large light areas in a movie is not controllable by the viewer at all, only by the movie producer. This leaves brightness as the only truly controllable option for viewers.

Since the early nineties, 100 Hz PAL television sets have been introduced. One might think, that they solve the problem of flickering, as the refresh rate now is double as high. This is however not the case due to the conversion methods of 100 Hz television sets.

Two basic frequency doubling techniques exist and they differ in the order in which fields are repeated. If the standard interlaced video signal is represented by the following order of ‘O’dd and ‘E’ven fields: $O_1E_1O_2E_2$ (50 Hz), the first method (frame doubling) repeats fields at 100 Hz in the order $O_1E_1O_1E_1O_2E_2O_2E_2$The second method (field doubling) repeats fields at 100 Hz in the order $O_1O_1E_1E_1O_2O_2E_2E_2$This is the flicker reduction technique used by several manufacturers, since no interfield processing is required and only one field has to be stored in memory at any one time, thereby reducing memory costs...

If this [stereoscopic] video signal is displayed using the field doubling technique as discussed above, the field sequence will be $L_1L_1R_1R_1L_2L_2R_2R_2$ (100 Hz). This is not suitable for stereoscopic display because an effective 25 Hz display rate per eye is still perceived due to the grouping of doubled fields. However, if the display is implemented using frame doubling instead of field doubling with the display sequence $L_1R_1L_1R_1L_2R_2L_2R_2$ (100 Hz), an acceptable 50 Hz display rate per eye will result

Quote box 10: The problem of stereoscopy on 100Hz TV sets³⁵⁷.

Only few, expensive, television sets (e.g. those of the German manufacturer Loewe) use the $L_1R_1L_1R_1L_2R_2L_2R_2$ conversion method, so the arrival of 100 Hz television sets do not solve the problem of flickering when viewing stereoscopic content on TV

The European DVB standard is planned for using PAL TV sets, so this will not stimulate the development of TV appliances capable of higher refresh rates. Neither the new US HDTV standard, offers anything usable, the highest refresh rates within

³⁵⁶ Starks,.

³⁵⁷ Woods, et.al., 1991.

the standard being 60 frames per second (progressive) and 30 frames (60 fields) per second (interlaced).

The issue of stereoscopic television is nevertheless the subject to the attention of the European Broadcasting Union:

*No satisfactory method has yet been found for giving an impression of relief in television (3-D). One of the main problems is that systems relying on colour separation create an artificial impression. Researchers are today investigating techniques using neutral polarized glasses. With all these systems, viewers would be required to wear glasses. To overcome this drawback, one of the long-term possibilities being explored is the design of picture tubes incorporating lenses that present images separately to the left and right eye.*³⁵⁸

The methods referred to in the quote are probably the method referred to below, which covers each scan line with alternating polarizing strips. The second one is likely to be the use of lenticular sheets mentioned on page 215. Both of these suggestions are somewhat far fetched, considering the status of the installed base of TV sets in Europe. A more obvious solution would be expanding the DVB standard, which at present only allows video of 50 frames per second in progressive scan³⁵⁹. If thus extended to also incorporate 50 frames per second using *interlaced* scan, the DVB standard would be very useful for interlaced stereoscopic content, yielding a total of 100 fields per second, which is sufficient to avoid flicker.

9.3.2. The Computer/networking Sector

The computer/networking sector makes use of a variety of display devices, among which the CRT monitor is the best known. Lately, new monitor types have arrived, offering new possibilities, but also removing some options characteristic of the CRT monitor.

As alternatives to having the picture displayed on a monitor, the computer can be connected to a projector throwing the image onto a large display surface. This is particularly relevant in situations with larger audiences.

9.3.2.1. Monitors

Compared to TV sets, computer CRT monitors are very flexible devices. Being capable of progressive scan and frequencies often up to 150 Hz, they are well suited for stereoscopic use with shutter glasses. Their main problem is so called *persistence* or *ghosting*, which appears as a remnant of the previous frame being noticeable. This

³⁵⁸ Peters, 2002.

³⁵⁹ ETSI Secretariat, 1997, p.21.

is due to the persistence of the monitor, and results in a “ghost image” of the left eye in right eye’s frame and vice versa. This problem is however negligible with newer, relatively fast monitors.

The newer flat screen LCD and plasma monitors are much slower than CRTs and exhibit ghosting at degrees that make them unsuitable for stereoscopic viewing. They do, on the other hand, have other potentials. By polarizing each even pixel line in the monitor in one direction and every odd pixel line in the other direction, interlaced content can be viewed with polarizing glasses. A “Venetian blind” effect is likely to appear, though. Another possibility is adding a lenticular sheet on top of the screen, and via a modified driver having the computer output an image, which, viewed through the lenticular sheet, is stereoscopic. Both of these solutions are in their infancy, and only few actual implementations exist.

9.3.2.2. Projectors

Computer CRT monitors are usually much smaller than TV sets (typically 17 inches in diagonal where a TV set often is 30 inches). Therefore, they are not particularly useful when applied to a living room usage scenario where a family of e.g. five people view the same picture. Here, a nearby solution is the use of a projector. Three fundamentally different types of projectors exist



Figure 44: BARCO Cine9 CRT projector³⁶⁰.

CRT projectors are the oldest type, based on three red, green and blue cathode ray tubes projecting the image onto a surface. Recent models are capable of refresh rates over 100 Hz in high resolutions – e.g. 1027x768, and are as such well suited for use with shutter glasses³⁶¹. Main drawbacks are the persistence of especially the green tube, considerable size and weight (often over 50 kg), and high price – often ranging above US\$ or € 20.000, CRT projector for private use are mainly purchased by wealthy home cinema enthusiasts.

³⁶⁰ Picture from BARCO projection systems website:

http://www.barco.com/projection_systems/products/product.asp?element=874 - link active per 020704.

³⁶¹ The usability of various projector types has been subject to investigation and experimentation in the MultiModality Proof-of-concept Prototype.



Figure 45: Canon LV-7105 LCD projector³⁶².

LCD projectors are by comparison much smaller, cheaper and easier to operate than CRT projectors. They are probably the most numerous type in use today, often used for presentations at meetings, demonstrations and similar activities. Unfortunately, they are not usable with shutter glasses due to their considerable persistence. They can, however, be used for polarized projection with a two projector set-up and some modifications due to the inherent polarization of the internal LCD screen.



Figure 46: InFocus 500 DLP projector³⁶³.

DLP projectors resemble LCD projectors to the extent that one has to look inside to see the difference. This difference is primarily in the way, that the picture is generated. While the LCD projector uses one or more small, translucent LCD screens, the DLP type uses a DMD (a digital micromirror device), which is a small chip with around a million small mirrors (one for each pixel) switching on and off, hereby generating the image aided by a rotating colour wheel. Available at prices starting around US\$ or € 3.000, the LCD and DLP projectors are more suited for a household budget than the CRTs.

The DLP projectors are in principle well suited for stereoscopic viewing with shutter glasses, because the DMDs have capacities way above the 100 or 120 Hz necessary for flicker-free viewing. Unfortunately, the projectors have limitations elsewhere, as the rotation speed of colour wheels imposes refresh rate limitations. We speak of the projector having a *native refresh rate* depending upon the colour wheel speed and number of colour segments. When fed a signal with a refresh rate other than the native

³⁶² Picture from EDBpriser.dk website: <http://www.edbpriser.dk/hardware/hardware-top10.asp?ID=1844637899> - link active per 020704.

³⁶³ Picture from The Home Theater Marketplace website: <http://www.marketware-tech.com/infocdlphomt.html> - link active per 020704).

one, an internal frame rate converter sets in³⁶⁴, converting the input rate to the native one, hereby destroying the sync between the projected image and the shutter glasses. The native refresh rate is typically around 60 to 75 Hz, which gives perceivable flicker. Newer DLP projectors are rumoured to have higher native refresh rates around 100 or 120 Hz, but in spite of extensive searches and inquiries, none have been identified so far.

Rather than using a colour wheel, some high-end DLP projectors use 3 DMD chips, each yielding a different colour, to generate the images. These are not restricted by the low native refresh rate determined by colour wheel speed. Unfortunately, they are prohibitively expensive for the average household use.

Depending on the future development – either through the increase of native refresh rate or by the falling of prices of 3-chip DLP projectors to the present level of low-end projectors, the DLP projectors stand a good chance of becoming the stereoscopic living room display device of the future. Until this becomes reality, the DLP family of projectors are also well suited for a dual-projector setup with polarizing panels, as they lack the internal polarization present in LCD projectors.

9.4. Appliances

In the TV sector, the main appliance is one unit containing the display device. On a computer, by contrast, the display device is separated from the main appliance giving more choice in the combination of components. Furthermore, the computer has processing capability, enabling it to translate virtually any stereoscopic format to a usable form by use of an appropriate application. Where the television set is limited to only displaying interlaced content, the computer can output almost whatever stereoscopic format in page-flipped form to its monitor.

Even for playing an interlaced stereoscopic video tape – a storage medium and stereoscopic format directly targeted to the television sector – the computer can improve viewing quality. If using a graphics card with video input, a VCR playing the stereoscopic tape can be connected to the computer. By using a special piece of software³⁶⁵, the interlaced signal is converted by the computer to page flipping at whatever refresh rate the monitor can accept, thus eliminating the inevitable flicker on 50 or 60 Hz TV sets.

³⁶⁴ Information is from email correspondence with Davis developers in Norway.

³⁶⁵ This software is made by graphics card manufacturer ASUS and is called VrPlayer. When ASUS first began making stereoscopic graphics drivers, this application was included in the driver package. At some point in time, for unknown reasons, ASUS stopped distributing VrPlayer, which was a great loss to stereoscopy enthusiasts, as it was by far the superior way of watching stereoscopic video tapes.

9.4.1. Applications

For the computer to make use of its processing power, it must have software – applications controlling the presentation of the content. This dichotomy does not exist in the television sector, the appliances of which have no processing power. They depend upon media, which suit their ways of working without any possibility of conversion – with the interlaced stereoscopic video tape as the main example.

As stereoscopy has not (yet) become a mainstream phenomenon on computers – let alone on television – significant numbers of the specialized pieces of software available is developed by small companies and individuals. For making and watching stereoscopic movies – an infocom form originating from the television sector – much of the available applications are freeware. A very typical example is the Win3D video player developed by Czech chemist Michal Husak³⁶⁶. This player enables the computer to output virtually any format of stereoscopic video file to the monitor in page flipping, anaglyph or side-by-side mode. The same functions are undertaken by Stereographics' Parallax Player³⁶⁷, which by contrast is a commercial product by a well established company.

Also the streaming video formats known from the Internet have been subject to stereoscopic innovations. For the most common formats, player plug-ins have been developed, which enable the streaming and viewing of stereoscopic content. For Windows Media Player and RealPlayer (aka RealONE), Isee3D have developed plug-ins allowing the viewing of stereoscopic video in anaglyph form as well as page flipped for shutter glasses³⁶⁸. For the third major streaming format, Apple's QuickTime, the OpticBoom plug-in has been developed, likewise allowing the viewing of streamed stereoscopic video with shutter- as well as anaglyph glasses³⁶⁹. Though introduced around year 2000, none of the systems have achieved wide adoption.

Another system doing stereoscopic video streaming is DepthCharge by VRex³⁷⁰. This software differs from the ones mentioned above, as it is a plug-in for a browser rather than for a video player. Furthermore, it works as a stand-alone video player. It is able to play its own .vrr and Microsoft's .wmv file formats and supports a variety of methods for viewing, however *not* page flipped.

³⁶⁶ This software – plus other appliances – can be downloaded from Michal Husak's homepage at <http://mysak.umbr.cas.cz/~husakm/Public/Win3dVideo/Win3dStereoscopicVideoPlayer.htm> (link inactive per 020704).

³⁶⁷ Description can be seen at the Stereographics website at <http://www.stereographics.com/preview/parallaxplayer/> - link active per 020704.

³⁶⁸ Isee3D press release, 2000.

³⁶⁹ Dynamic Digital Depth website.

³⁷⁰ www.vrex.com

It is interesting to note, that these third party plug-ins to the video players (and hence to the proprietary file formats of very well established software- and service providers) are being developed by considerably smaller companies specialising in stereoscopic content.

For gaming purposes (and other purposes involving the Direct3d and OpenGL 3D APIs), stereoscopy-capable drivers are developed by large hardware manufacturers³⁷¹. This has not always been the case. In the mid-nineties, when household computer stereoscopy was evolving, stereoscopic game drivers such as Wicked3D by Metabyte³⁷² and VRCaddy by VRStandard³⁷³ were made by comparatively small companies.

In general, the tendencies go towards larger and well-established companies entering the business of stereoscopy. This is especially true in the computer gaming area, and to some extent the case in the area of streaming stereoscopic video, while the area of software for generating and playing stereoscopic video files still is dominated by the very small companies and hobbyists.

9.5. Content

The success of stereoscopic appliances and applications – video players and 3D API drivers as well as display devices – depend heavily upon the available content, and vice versa. Without the suitable appliances and applications, the incentive for production of content is missing, and if no content is available, the incentive for development of hard- and software will likewise be absent.

Thus, the content (stereoscopic movies, games, etc.) acts as *complementary assets* as described by Teece on page 78 in relation to the appliances. In more specific terms, the content act as *co-specialized assets*, in relation to the specialized stereoscopic hardware (e.g. shutter glasses, which have no other purpose than stereoscopy). In relation to the multi-purpose hardware of computers and TV sets, which have other purposes than stereoscopy, the stereoscopic content acts as the type of specialized asset, that depend unilaterally upon the basic service or product.

The computer/networking sector stand a better chance of overcoming the chicken-and-egg problem of appliance-content interdependence, due to the flexibility it possesses. As long as only software is necessary for a new form of content to run on a computer, the introduction of this content is less demanding than if it requires a new hardware

³⁷¹ Most prominently by ELSA (a now bankrupt German graphics card manufacturer), ASUS (graphics card and motherboard manufacturer) and NVidia, who produces chips for graphics cards (used by a.o. ELSA and ASUS).

³⁷² www.metabyte.com.

³⁷³ www.vrstandard.com.

component – i.e. to overcome the chicken-and-egg problem as described on page 164. The importance of being able to run new stereoscopic services on the existing installed base of appliances is illustrated by Shapiro and Varian, who point out, that:

”It is hard for a new virtual reality product to gain market share without people having access to a viewer for that product...but no one wants to buy a viewer if there is no content to view.”³⁷⁴

This section presents the typical form of stereoscopic content for the two sectors of television and computer/networking, and identifies a number of key characteristics of the content generation.

9.5.1. Movies

The converging sectors compared and analysed in this project are those of television and computer/networking. Stereoscopic movies, however, had their days of glory in movie theatres, and the conversions made later for viewing on television do them little justice. Though moving pictures is seen as a phenomenon characteristic of the television sector, the background of stereoscopic movies cannot be understood without considering the movie theatre industry, which therefore is included in this section.

An important aspect of stereoscopic movies is, that the source material must be stereoscopic. From the outset, the movie must be planned as a stereoscopic one. It can, of course, later be shown as a monoscopic movie, but the opposite - turning a monoscopic movie into stereo – is not practically possible³⁷⁵.

The boom in stereoscopic cinema productions took place in USA in the early fifties. Threatened by television³⁷⁶, stereoscopy – or “3-D” was seen as way of adding value to the movie experience, which only cinemas could offer. With the majority of the movies shown with the polarization technique, the audience could still see the colours. Later conversions to anaglyph format for viewing on television discarded the colour information, giving a much poorer experience among television viewers.

³⁷⁴ Shapiro & Varian, p.189.

³⁷⁵ Lately, conversion software claiming to turn one-dimensional movies into stereoscopic ones have arrived, but reportedly, the quality of the resulting material is questionable. See e.g. http://www.stereo3d.com/3dplus_software.htm for a review

³⁷⁶ Erickson, 1998.

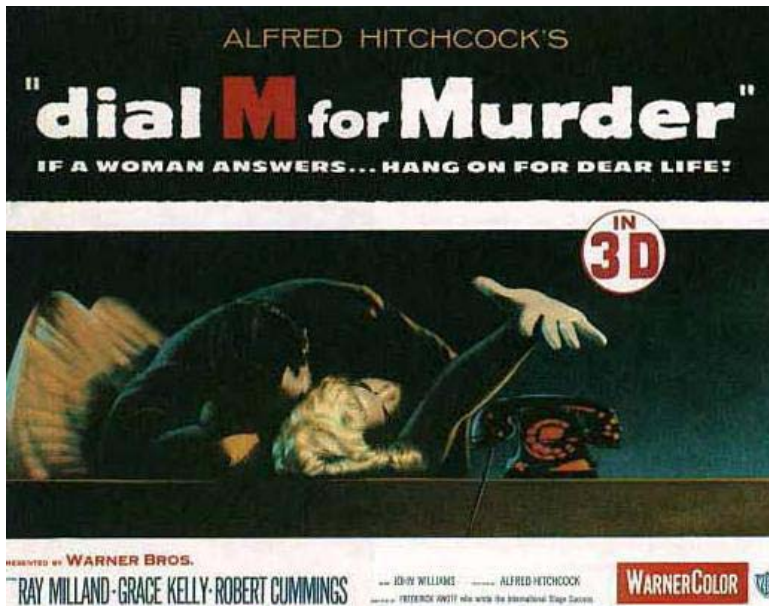


Figure 47: Alfred Hitchcock's stereoscopic "dial M for Murder" (1954)³⁷⁷

The main problems with stereoscopic movies in cinemas arose in the early to mid fifties, and were related to the distribution and exhibition rather than production. Movie rolls not arriving at theatres as well as ill-adjusted and misaligned projectors lead to audience dissatisfaction, which in turn resulted in resistance from exhibitors. This reflected on the studios, which moved to lower-budget stereoscopic films, further reinforcing the disregard among audiences.³⁷⁸

The showing of stereoscopic movies on television probably only made matters worse. Lacking any opportunity of keeping colour information, as the polarization technique demands two separate projectors, and shutter glasses are a fairly recent invention (which – if applied – would have given very noticeable flickering), the anaglyph method was used. Introduction of a new, stereo capable television system has not been an option – getting relatively few movie theatres to invest in stereoscopic equipment is perhaps possible, but having millions of private homes buy new appliances is a project of immense proportions.

The situation today is characterised by a widespread disregard for stereoscopic movies, with the occasional 3-D movies being regarded as a curiosities. One recent exception is Terminator II 3D, a 12 minute theme park attraction, incorporating new

³⁷⁷ Poster from the Advertising Hitchcock website (online reference: <http://advertisinghitch2.tripod.com/DIALM/dialtwo.htm> - link active per 020705)

³⁷⁸ Erickson, 1998.

filming 3D animation as well as presentation techniques – e.g. the use of twinned 70mm cameras running 30 frames per second instead of the traditional 24 fps.³⁷⁹

No movies remotely resembling the stereoscopic movies of the fifties in terms of quality³⁸⁰ have been released since then. Enthusiasts of 3D movies are focusing their attention on the 3D movies of the fifties, attempting to persuade copyright owners to reissue the movies in field-sequential format on DVD. An example of this is the “House of Wax on DVD” petition³⁸¹ to Warner Bros Home Video Division, trying to persuade the company to release the 1953 3-D classic “House of Wax” in stereoscopic format - preferably field-sequential, according to those who have signed the petition.

9.5.2. Games

Just as movies are the form of stereoscopic content most typical to the television sector, computer games are the applications in the computer/networking sector where stereoscopic innovations and adoption is most significant.

While stereo movies have to be produced stereoscopically from the beginning, 3d games have had the information necessary for the 3D API (application programming interface) to generate stereoscopic views long before stereoscopic drivers were developed. This information is used by the computer to do the rendering of 3D environments, and is included in the games regardless of any stereoscopic considerations. Those developing stereoscopic computer equipment have not had to speculate upon how to ensure the content. It was already there!

This fact that this prerequisite was already in place has undoubtedly given stereo computer gaming an easy start. The chicken-and-egg problem that characterises television stereoscopy is completely avoided.

The first games to be based on a 3D API were first person shooter games (as e.g. Quake), and car and flight simulation games. Later, many strategy and adventure games moved to 3D APIs, further increasing the installed base of stereo-capable computer games.

With the advent of completely computer generated movies such as “Final Fantasy” mentioned in the Hybrid Communication and Information Case Study, the content problem of stereoscopic movies could be solved in similar ways to that of the computer/networking sector. As is the case of 3D computer games, the information

³⁷⁹ Parisi, 1999.

³⁸⁰ While quality is a subjective term, it is widely accepted among stereoscopy enthusiasts, that virtually everything since the sixties have been - at best – B-movies.

³⁸¹ “House of Wax on DVD” petition, <http://www.petitiononline.com/8519/petition.html> - link active per 020709.

necessary for stereoscopic rendering is already present in the raw material for such movies. The earlier mentioned problem of not being able to “turn 2D into 3D” does not exist here. Rendering a stereoscopic version of the movie is not more difficult than rendering a monoscopic one. Still, actual examples of this are yet to be seen.

9.6. Conclusion

It is apparent, that the development in stereoscopy is taking place at a much faster rate in the computer/networking sector than in the television sector. A number of factors described below indicate, that this is likely to be the case in the future as well. It is therefore probable, that the computer/networking sector will act as a driver in this field, especially for two reasons:

- The computer/networking sector has a wide variety of content available.
- The computer/networking sector is able to process and display a wide variety of stereoscopic formats.

In case the supply of stereoscopic content increases, and the market potential to movie studios and TV set manufacturers becomes obvious, these groups of the television sector might adopt the workings of computer/networking sector’s appliances, hereby contributing to the convergence process.

9.6.1. Flexibility

Not only are the computer CRT monitors much more flexible than CRT TV sets. The computer is also able to use a variety of projectors, hereby rivalling the TV set as an appliance for viewing of stereoscopic content in a usage scenario with larger groups. Though being considerably more expensive than a TV set, the viewing quality of computers is considerably better.

The opportunities of consuming stereoscopic content are much more numerous in the computer/networking sectors than in the television sector. In relation to available content, the computer is able to process not only its “own” content in virtually whatever stereoscopic format one could desire, but also that of the television sector. Also as to the display capabilities, the computer is able to make use of a wider variety of stereoscopic separation methods.

9.6.2. Installed Base

The problems concerning installed bases of inflexible appliances is especially significant in the television sector, where the many television sets in private homes are incapable of displaying stereoscopic content in a satisfying quality. Especially due to the traditionally long periods of standstill between large leaps in innovation in the television sector (as illustrated in Figure 24 on page 166), introduction of new

methods and standards is a considerable problem in this sector. The installed base of appliances in the computer sector does not hamper development to the same degree. The appliances are inherently flexible due to the adjustable resolutions and refresh rates, and even more so due to the distributed calculating power, the option of installing the appropriate applications for any chosen stereoscopic separation method and video format, plus – if necessary - the option of upgrading specific components (e.g. graphics cards) due to the modular composition of computers.

9.6.3. Communication networks or Hardware-software systems

The applications presented in this chapter have been of a hardware-software nature. For stereoscopy to assume the properties of communication networks, it should be used for interpersonal communication. Though experiments with stereoscopic webcams have been carried out (as mentioned on page 378 in relation to the MultiModality Proof-of-concept Prototype in the appendix), the use of stereoscopy in such settings is very limited³⁸²; the majority of uses being within the domain of hardware-software systems.

Therefore, the very strong feed-back mechanisms of communication networks with their direct external effects can not be expected to apply to the area of stereoscopy. Nevertheless, it is probable that one separation method and one stereoscopic format of content will become dominant, but this will be due to the indirect externalities in the form of economies of scale as a result of buyers' adoption decision as described on page 76. Also the effect of support networks, introduced in the theory chapter on page 77 can influence the adoption process, especially in the earlier stages of any future growth of stereoscopic consumption.

9.6.4. Positive Feed-back

Regardless of whether stereoscopy is used in communication networks of purely in a hardware-software system setting, there is reason to believe that some form of positive feedback will apply to any future adoption process. In the present market situation, where stereoscopic content as well as appliances are not at all mainstream, these mechanisms have not yet come into play. As mentioned above, the future role of positive feedback is highly dependant upon the future usage of stereoscopy.

³⁸² Projects funded by the European Commission have been targeted at stereoscopic interpersonal communication. A project, DISTIMA (1992-1995) ran under the RACE programme, and continued under the ACTS programme as PANORAMA (1995-1998). Practical implementations of these projects have not been identified. (online reference: <http://ec.eurecom.fr/~chappuis/rapport/node5.html> - link active per 020711)

9.6.5. Complementary Assets

Being able to turn much of the existing 3D based content into stereo, the computer-based stereoscopy has a much wider range of complementary assets stimulating the adoption of stereoscopic viewing in this particular sector. Stereoscopic television, by contrast, is characterised by a scarcity of content.

In the field of stereoscopic movies, which is the form of content most native to the television sector, a chicken-and-egg problem is hampering the further development. This problem does not exist in the computer/networking sector, where much content happens to be stereo-ready due to the way 3D environments are created.

9.6.6. Path dependence

As mentioned earlier, both the U.S. and European digital standards for television would be capable of doing field-sequential stereoscopy, if standards were extended to incorporate higher refresh rates. It is tempting to apply a perspective of 3rd degree path-dependence to the development of television standards, the logic being, that with the transition from analog to digital television, the standardisation organisations have a chance of remedying the lack of high-quality stereoscopic capabilities that were inherent to the old systems. This is, however, hardly the case. No evidence has been observed, that stereoscopy is – or ever has been – any major concern of the standards developing bodies involved in television standardisation. Though the transition from analog to digital television might be seen as *the* chance of remedy among stereoscopy enthusiasts, it is not likely that a corresponding view exists among standardisation authorities – or among the majority of viewers for that matter. For 3rd degree path dependence to be the case, the choice done at point in time when remedy was possible should be sub-optimal. Though the solution is sub-optimal with stereoscopy in mind, it is not an objective truth that a better choice could have been done.

9.6.7. Reverse Salients

As in the case of 3rd degree path dependence, it could be interesting to regard the lack of stereoscopic content and display capabilities as a reverse salient of the television system. For similar reasons as in the path dependence case, this is a doubtful. For this to be the case, one would expect much focus on the lack of stereoscopic opportunities. The interest in stereoscopy among viewers and content providers such as TV stations and movie companies would have to be much greater than is actually the case in order to label the incapability of television appliances as a reverse salient.

9.6.8. The Promise of Quality

With the maximum of 50 or 60 Hz (i.e. 50 or 60 fields per second) progressive scan in both HDTV and DVB, the television sector's appliances are not likely in the near future to be able to display stereoscopic video for viewing with shutter glasses. For this to be possible the specifications must include at least 50 or 60 frames per second interlaced³⁸³ or 100 or 120 frames per second progressive. Therefore, the "promise of quality" of convergence is not likely to be fulfilled by the television sector.

The promise is more likely to be fulfilled by the computer/networking sector's appliances. The major obstacle is the small size of computer CRT monitors, making them ill suited for living room type usage scenarios. With the introduction of large LCD and plasma screens (which are not suited for field-sequential mode due to their latency) , CRT technology is likely to be considered obsolete, and cheap and large computer CRT monitors can not be expected. For the TVPC to become the future appliance on which to watch stereoscopic content, the most likely display device is the DLP projector, only needing to achieve 100 or 120 Hz native refresh rate – a development which is not unlikely to be a result of incremental development.

9.7. Outlook

Stereoscopic broadcasts and pre-recorded media for the television sector are few and far between. Due to the strong interdependency between hard- and software in the television sector, stimulating the use of stereoscopy in the television sector is difficult.

If stereoscopy should gain momentum in the future, this would probably be driven by the computer/networking sector rather than the television sector. Here, the opportunities of hybrid communication and TVPCs (the two other case studies) can substitute the stereoscopic TV broadcasts. Using the infrastructure of the computer/networking sector – and thus avoiding the rigid specifications of TV signals, the content can be encoded to whatever stereoscopic format one should desire. Using the flexible TVPC appliance, any desired separation method would be available.

³⁸³ 50 or 60 frames per second interlaced equals 100 or 120 fields per second.

10.The Hybrid Communication and Information Case Study

One of the important promises of convergence presented earlier is *interactivity*. Interactivity in the form of consumer's choice of information and communication. Choice of what to consume, when and in which form to consume it. This can be an active form of interactivity, seeking information and controlling the presentation of the content (often referred to as *lean-forward interactivity*), or a form of interactivity more having to do with selecting the choice among alternatives that best fits the preferences of the user (correspondingly referred to as *lean-back interactivity*). It can be something in between these two forms representing a whole spectrum of interactivity rather than being discrete alternatives.

10.1. Introduction

A main feature distinguishing the television and the computer/networking sectors is the way in which the information is distributed. Here, the sectors display even larger differences than can be observed in the field of appliances. As has been described in the taxonomy on page 123, compared to the way television is distributed, the internet has a number of capabilities which makes it better suited for communication forms that are more interactive in nature. On the Internet, users can choose the exact piece of information they want, and often even decide in which form the information should appear.

Many of the features of the Internet are sought implemented in television programmes, but these attempts are hampered by the rigidity of the TV appliance and the lack of a return path, as television is developed for consuming audio and video with teletext as the most advanced form of selectable text based content.

Assuming that broadcasters as well as viewers want a higher degree of interactivity, two major development paths are often predicted. One involves the development of a return path in future digital TV broadcasting systems, while the other expects some degree of incorporation of Internet in television. This case study looks at the content delivered and the infrastructures over which it is transferred. It describes the options of transmitting traditional television content via the Internet, and presents the basic considerations underlying the integration of varying amounts of computer/networking content in television. Finally, it proposes a combination of the content of the two sectors based upon the existing technical possibilities and the fundamental characteristics of the programmes.

10.2. Content of Infocom

Traditional television content is composed by moving pictures and sound. During the early decades of television, this was the only form of content available. Interactivity was limited to the option of selecting a different channel. In the seventies, teletext,

described in the taxonomy chapter on page 105, was developed in Europe, allowing users to see simple text-based information, still without true interactivity, as the appearance of teletext pages are fixed³⁸⁴.

Not only the modality of information (whether it is black/white or colour, whether it is text based or sound, etc), differs from programme to programme. Other, less tangible, characteristics apply to the content. Some information is desired by large groups of viewers, while others have a much narrower interest. Some information is rather consumed in real time (as the events that they portray happen), while other forms remain to be interesting no matter if they are consumed at a later point in time.

Thus, we can define two important dimensions of a TV programme:

- Importance of Immediacy – describing how important it is to viewers to see the events as they happen (or at least soon after they happened).
- Scope of Interest – describing if the programme appeals to large or small parts of the viewers.

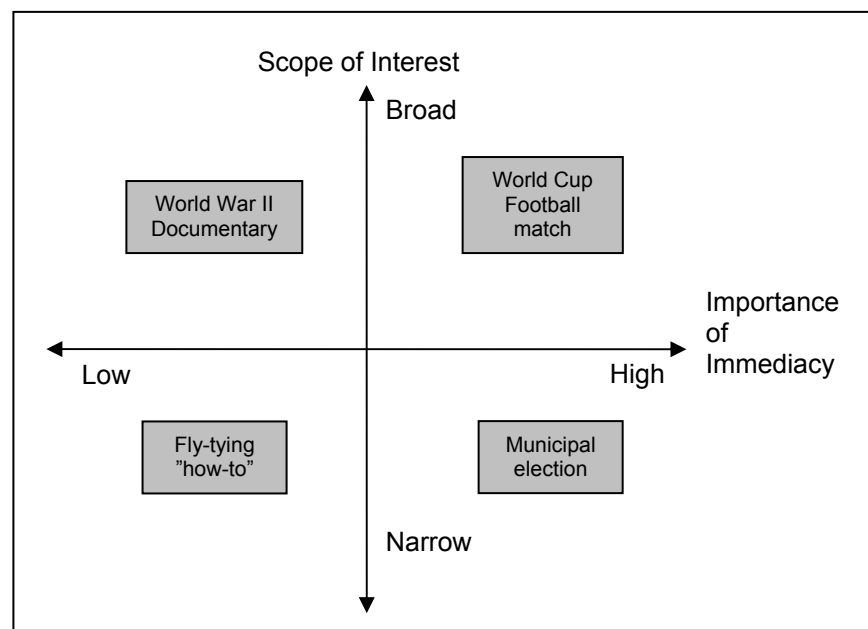


Figure 48: Examples of scope of interest and importance of immediacy of television programmes.

³⁸⁴ Teletext is an example of so-called "carousel" interactivity. The TV set cycles through all of the existing teletext pages for a particular channel, displaying the page selected by the user.

Regarding the importance of immediacy, there is another parameter that – while not exactly being the opposite of immediacy - nevertheless could be seen as belonging in the other end of the X-axis in the figure. This is the availability – i.e. the availability at any time desired by the recipient.

The examples of various programmes in the figure might not be completely obvious. Therefore, a short explanation of the four examples follows³⁸⁵:

- A *world cup football match* is generally regarded as one of the important events among football enthusiasts. Because football is a relatively popular sport, it appeals to a large number of viewers (hence the high scope of interest). Furthermore, there is a tendency towards sporting events being preferred as live broadcasts rather than being viewed later, which accounts for the high importance of immediacy.
- A *municipal election* is only of interest to a limited number of viewers, primarily those living in the municipality in question. While highly topical at a particular point in time, it is doubtful whether a programme about a past election would interest any viewers at all.
- A *documentary on the Second World War* is likely to interest a large number of historically inclined viewers. While thus having a large scope of interest, there is nothing making this type of programmes suitable for being viewed at any particular point in time.
- Similarly, a *tutorial on how to tie one's own fishing flies* is not particularly suited for being viewed at one particular time. Indeed, it would often be more useful to have *availability*, i.e. for the viewer to decide when to view the programme (e.g. in advance of a fly-tying session). What makes such a programme different from the World War II example is, that it is likely to appeal to a much smaller group of viewers, as fly-fishing is a hobby of relatively few people.

While the characteristics in the above figure are illustrated by types of TV programmes, they can also be applied to specific types of information. While, for example, the standings and the time remaining in a football match is of interest to a large number of viewers, statistics on one particular player would be of narrower interest.

Especially such forms of supplementary information as statistics, background, etc are problematic in today's paradigm of television. Therefore, a producer has to decide when a particular piece of information is sufficiently interesting to a sufficiently large

³⁸⁵ The claims concerning the preferences of viewers are based upon the author's own experience, so there is no acknowledged source behind these postulates. They are regarded as commonly accepted facts.

part of the audience to justify displaying this information – hereby irritating those who do not need or desire the information. The obvious solution to this dilemma is to make it possible for the viewers to bring up such information when they want to. Unfortunately, this is not possible within current television systems. The phenomenon that comes closest is teletext, but due to the limited bandwidth³⁸⁶ and lack of graphical options, the potential is very limited.

These different forms of information – text, graphics, pictures etc. are described in the chapter containing the information and communication taxonomy. Here, the taxonomy's *user interface* table on page 113 lists a number of modalities, characteristic of the established information and communication forms in the various sectors. This chapter analyses the opportunities of mixing and matching such information *across* sectors.

10.3. Interactivity

Among the many visions of interactive television, the one illustrated above is easily comprehensible. It is fairly obvious, how viewers can benefit from being able to call up additional information to the extent, they desire. Considering that this is not realistic in traditional analogue television, *interactivity* can be regarded as an important *reverse salient* (as described in the theory chapter on page 352) of the television sector. There has been some attempts of involving viewers in TV programs by letting them interact via the telephone, but no form of interactivity resembling what it possible on the internet has been achieved.

The much attention given by broadcasters to the topic of interactivity suggests that it is an important reverse salient in the television system. Whether it can be remedied within the television system is uncertain. Standards such as Multimedia Home Platform (MHP) and NorDig incorporate interactive features such as electronic programme guides and supplementary information about programmes. Hence, digital television might well remedy this lack of interactivity. However, a shift in system might occur if the implementation of such services last too long, and if alternatives on the Internet have sufficient time to solidify themselves.

There is, however, means of remedying this lack. It is obvious, that the elements of information, which are narrow-interest and have a low importance of interest are well suited for delivery via a system, which can store accessible information and deliver it to the consumer upon request. Such a system is the Internet, with its multitude of servers storing information in virtually any form desirable. The main problem in using

³⁸⁶ Teletext is transmitted in the so-called Vertical Blanking Interval or VBI, a period of time where the electron beam after having painted the picture on the screen returns from the bottom to the top. Teletext utilizes this interval for transmitting its content, but the VBIs do not leave room for very large amounts of data.

the Internet in combination with traditional television lies in the rigidity of the appliances. There are no easy means of displaying the HTML coded information on a television set.

One might expect the coming of digital television (DVB in Europe and HDTV in North America) to solve this problem. This is however not necessarily the case, at least not in Europe, where DVB is planned as initially being sent as an interlaced signal only. Interlaced pictures are less suited for text and graphics, a fact that will hamper the development of supplementary text and graphics based services.

"It's a roadblock on the way to convergence," ... "It accommodates only low-resolution text and graphics if you want to avoid flicker. The Web is full of text and graphics and hence inherently ill suited to interlace scanning"

Quote box 11: Alvy Ray Smith, former Microsoft graphics developer, on the drawbacks of interlaced scan³⁸⁷.

10.3.1. Intericast

An early, serious attempt of delivering HTML based information supplementing TV broadcasts was Intel's Intericast system. Instead of delivering the rather coarse-looking teletext in the VBI, it transmitted HTML, the basic language used for Internet pages. Introduced in 1997 on the German channel ZDF³⁸⁸, it never achieved any wide acceptance and was soon abandoned by Intel in favour of the ATVEF system.

Due to the traditional television set's lack of HTML capability, Intericast relied on a computer equipped with a TV tuner card³⁸⁹ (i.e. a TVPC as described in the case study of this particular appliance) as the device on which to consume Intericast pages. Hereby utilizing the hard disk for storage, Intericast pages could be downloaded in large numbers for later reading without the latency known from traditional teletext on a TV set.

10.3.2. ATVEF

As mentioned above, Intericast was short lived, as Intel decided to opt for the ATVEF (Advanced Television Enhancement Forum) specification for VBI-borne interactive content on television. The ATVEF is a consortium founded by CableLabs, CNN, DIRECTV, Discovery, Liberate, Microsoft, NBC, NDCT, PBS, Sony, Tribune, Disney and Warner Bros. Though strongly backed, ATVEF is not the only suggestion

³⁸⁷ Eisenberg, 1998.

³⁸⁸ Intericast Industry Group, 1997.

³⁸⁹ IBID

on how to integrate alternative text- and graphics based information such as HTML into television. A large number of alternative systems exist³⁹⁰, and at present, it is not possible to point to any standard being sufficiently dominating to be a candidate for *the* one dominating system. ATVEF is not an exclusively North American specification. Initiatives aimed at integrating the ATVEF specification into the European DVB has been initiated in 2000³⁹¹.

ATVEF cannot only run on a TV-tuner equipped computer. A number of stand-alone set top boxes are available, which when connected to a TV set makes Internet browsing possible. This way, users preferring either the ease of operation of TV sector appliances or the living room usage scenario can benefit from ATVEF as well. In order to achieve function, the set top box must be ATVEF-compliant, which is the case for a large number of appliances, among others products of Liberate and Microsoft³⁹²



Figure 49: Microsoft MSN TV ATVEF compliant set top box.

As has been indicated in the above, there is a multitude of suggestions, some open, some proprietary, that aims at delivering supplementary text- and graphics based information for television broadcasts. The existing confusion should not, however, overshadow the basic point of these paragraphs: The usefulness of delivering

³⁹⁰ Gurian contains a vast list of alternatives.

³⁹¹ DVB News, 2000.

³⁹² This is hardly surprising, as both companies are co-founders of ATVEF.

particular forms of information over one infrastructure, and other forms over another infrastructure – all depending on which is best suited for delivering the form of information in question.

Adding to the fierceness of the competition is the fact that the supplementary services – especially if based on proprietary standards – can act as important complementary assets supporting and adding value to e.g. a broadcaster's suite of programmes. Here, the SDOs, and RSOs as described in the “New Standardisation Fora and Their Relationships with Traditional Standardisation Organisations” paper in the appendix can have a well defined role to assume, namely as those ensuring the necessary openness and sufficient definition of standards in order to avoid consumer losses coming from lack of interoperability.

10.4. Internet-TV

The preceding sections have described combinations of infrastructures for various forms of information and communication. One prophecy often put forward does away with these considerations by suggesting that *all* content should be delivered via the Internet. And admittedly, there is nothing that a TV cable network can do, that the Internet can not. One major technical³⁹³ obstacle is however the congestion, which - with the current bandwidths available – inevitably will be the result of a multitude of viewers watching internet-borne television simultaneously. Bandwidth would soon become scarce, and the question is, whether television via Internet – at least in the foreseeable future – is efficient.

Disregarding the risk of congestion – for example by assuming that internet capacity is increased sufficiently as yet more consumers download large video files – the bandwidth necessary is not a far cry from what is currently available to private homes. With the increasing number of ADSL connections – often of 512 kbps or more, real time streaming³⁹⁴ of television programmes in an acceptable quality is absolutely possible. The conception of “acceptable quality” will of course differ according to tastes, but to give an idea of the necessary bandwidth, the following quote from Microsoft's description of their MPEG4 based WM8 codec can serve as an example:

While the quality of encoded video depends on the content being encoded, Windows Media Video 8 can deliver near-VHS-quality at bit rates ranging

³⁹³ Other obstacles to the complete migration of television onto the Internet apart from the purely technical ones exist. Broadcasters are reluctant to leave the established infrastructure due to their lack of control of the Internet.

³⁹⁴ Streaming video indicates that the video file is viewed by the recipient as it arrives. It is thus not necessary to download the whole file before starting to view it.

from 250 kilobits per second (Kbps) to 450 Kbps, and near-DVD-quality at 500 Kbps to several megabits per second (Mbps)^{395 396}.

Even a 500 kbps stream would be theoretically possible in many private European homes today. In principle, delivering video via the Internet is a viable alternative. Such a switch – a stepwise migration of content onto the Internet – is however not likely to appear in the near future. Even if the purely technical conditions were fulfilled, the content owners would have to accept having their intellectual property delivered via a network which is notorious for being used for intellectual property rights violations – most noticeably exemplified by the sharing of MP3 music files.

A more likely future scenario than having the Hollywood productions on the Internet is the emergence of a new type of content providers. As the barriers to entry are way lower for an Internet movie provider than for a provider seeking distribution via the traditional television channels, it is easier to establish oneself at the Internet. As long as demand is limited (i.e. the “scope of interest” as indicated in Figure 48), the type of network delivering information upon request to specific recipients (i.e. the Internet) is perfectly suited for this purpose. If sufficiently successful, such providers would have to count on a growth in Internet capacity matching their increased distribution – or alternatively, they would have to move to the traditional television sector.

Actual examples of such content providers are mainly found within the adult industry, delivering erotic video clips against payment, often on a subscription basis. To a larger extent substituting the traditional television broadcasts, many TV stations have their news broadcasts available on their websites for streaming. Finally, specific initiatives of delivering Internet-TV can be observed. An example is TVRopa, originally launched as an Internet based TV station, but not delivering anything resembling traditional television programmes, showing movie trailers as their most attractive content³⁹⁷.

10.4.1. Casting Scope

The main problem of the organisation of the Internet is that it is geared towards delivering content of narrow scope of interest, not at one particular time, but at the discretion of users. If every Internet user wanted to see a particular movie from the Internet, they would have to all require from the same server that it delivered them the movie. Alternatively, as described in the “Transmission” section in the taxonomy

³⁹⁵ Gill, 2001.

³⁹⁶ The author has carried out experiments with this particular codec under the proof of concept prototype related to “The TVPC Case Study”, and finds that – while a bit optimistic – Microsoft’s claim of quality are not far from the truth.

³⁹⁷ Based on a visit to www.tvropa.com in June 2002.

chapter (page 115), the TV sector uses a transmission form where all users connected receive all information.

When delivering programmes that *some* users, not only *one*, but on the other hand, not *all* users desire, a method of transmission in between these two extremes, *multicasting*, is necessary.

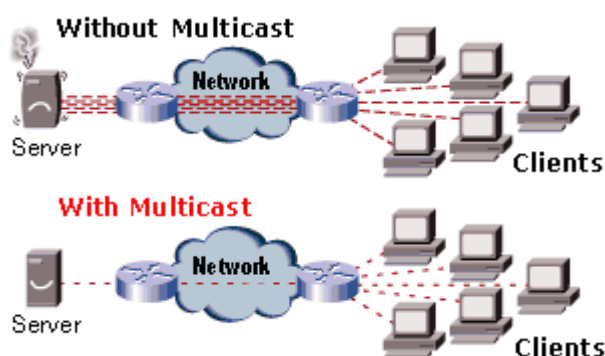


Figure 50: The basic difference between unicasting and multicasting³⁹⁸.

Thus, we have three different scopes of casting:

- Unicast: Communication taking place between one sender and *one* recipient
- Multicast: The sender transmitting a message to a *select group* of recipients.
- Broadcast: The sender transmitting a message to *all* connected parties.

Multicast was introduced in the Internet Protocol v6 (IPV6) by the Internet Engineering Task Force (IETF) in 1998. In order for multicast to work, the sending and receiving nodes as well as the network infrastructure between them must be multicast enabled³⁹⁹. Experiments and actual use of multicasting is centred around the dedicated multicast enabled backbone, the MBone (IP **M**ulticast **B**ackbone on the Internet) which is a set of interconnected IP multicast capable networks.

Though reducing stress on servers and consumption of bandwidth considerably, multicasting waives the benefit otherwise characteristic of internet-borne video: availability at any time.

³⁹⁸ Source: <http://www.cisco.com/warp/public/779/largeent/learn/technologies/multicast.html> - online reference - link active per 020626

³⁹⁹ Cisco Systems, Inc., 2001.

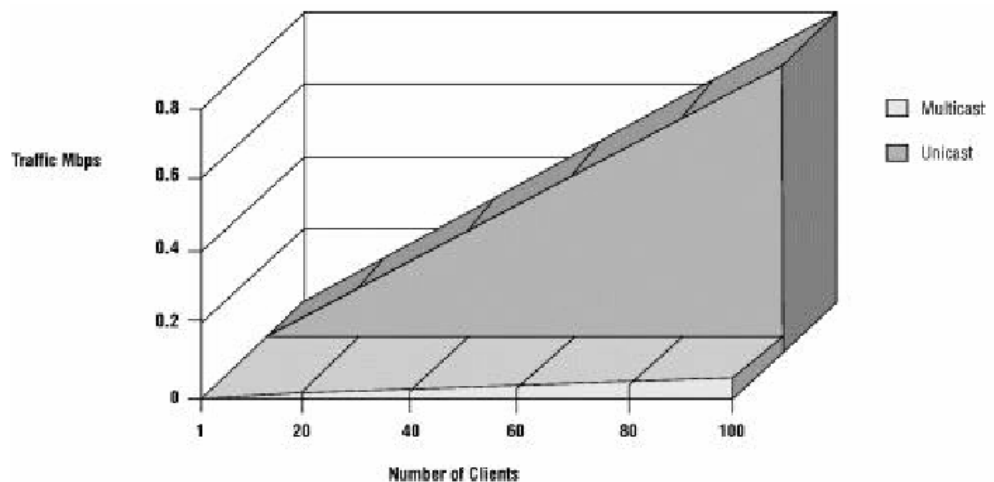


Figure 51: Illustration of bandwidth saving by using multicast instead of unicast⁴⁰⁰.

Whether and when multicasting on the part of the Internet used by common households will be available is not clear. It has not been possible to identify the actual adoption of multicasting, but if an intensive replacement of network components is necessary, it is likely to last years. A majority of a working group under the UK Radiocommunications Agency⁴⁰¹ estimated that by year 2005, "*Internet multicast is expected to be widely available and effective*". An increase in awareness of internet-borne video will be a considerable driver for such a development.

Lacking tailored multicast opportunities; distributors of large files – e.g. video files with television-like content – must rely on alternative technologies. One suitable solution is the use of mirror servers – regionally distributed servers holding the same content as the “master” server. This eliminates the connections going halfway around the globe, as the recipient only needs connecting to a server in close proximity. This is a system already known from the Usenet, where users connect to local news servers which in turn synchronise their content globally, ensuring – in the ideal situation, at least – that the system acts as one global news server. Similar principles are used by websites (e.g. tucows.com), which distribute free- and shareware. Unlike multicasting, these ways of distribution retain the availability of the content: users can access the server and view the content at their discretion.

⁴⁰⁰ Cisco Systems, Inc., 1999, p.4.

⁴⁰¹ UK Radiocommunications Agency, 2001.

No matter which ways the distribution is organised, an efficient way of sending television-like content is a precondition for the migration of TV content onto the Internet's infrastructure.

New Internet techniques, such as multicasting, offers the possibility of delivering audio and visual content to up to 50,000 users at any one time instead of 50,000 individual messages, narrowing the borderlines between previously separate sectors. Many consider that Internet will become a major conduit for video and sound (especially music) distribution.

Quote box 12: The European Commission's expectations of multicasting and related technologies⁴⁰².

As pointed out earlier in this chapter, the differing nature of different programmes and types of information makes it obvious, that a migration of television content to the Internet is not necessarily desirable. There are, however a number of programme types – especially those with narrow scope of interest and those, where accessibility at any time is desirable – which would be well suited for distribution over the internet to those with sufficiently fast connections.

10.5. Conclusion

This chapter suggests organising the information contained in television programmes and their supplementary services along two dimensions. The one having to do with on one side the importance of immediacy, on the other side the availability of the information at any time desired. The other dimension has to do with the scope of interest of viewers.

Programmes or supplementary services with low scope of interest, low importance of immediacy and/or high importance of availability are well suited for being broadcast over the Internet instead of using the traditional television distribution infrastructure. Therefore, a hybrid form of information and communication is proposed; one which:

- Utilizes the television broadcast infrastructure for what it does best: delivering real-time content to large groups of viewers, and
- Utilizes the Internet for what it does best: delivering narrow-interest information to users at any time they might desire.

Hence, a symbiotic co-existence between the two sectors of television and computer/networking will lead to a “best of both worlds” setting⁴⁰³.

⁴⁰² The European Commission, 1997, p.6.

Such a hybrid infocom service would probably be best consumed on a TVPC as described in its case study. There are a number of internet-capable set top boxes available, which might do the job, but users often complain that they are incapable of incorporating various html tags and other features, which can be enjoyed in an ordinary browser.

10.5.1. Complementary Assets

An important aspect of internet-borne supplementary services is that they can be offered by a large number of potential suppliers, as the barriers to entry into Internet based services are negligible compared to those of the television sector. This is not the case with those internet-capable set top boxes using a proprietary standard (mentioned on p.233). In this case, it is possible for the manufacturer to couple the box with his own supplementary service, thus having control of an important complementary asset.

10.5.2. Flexibility

The large number of potential suppliers of complementary services is a consequence of the flexibility of the Internet compared to that of the television sector. An obvious aspect of flexibility is in the standards of the Internet, where html and IP have proven to be important building blocks capable of delivering a wide variety of services. Another aspect has to do with the barriers to entry. Where an Internet service can be established by virtually anyone, the option of delivering programmes or supplementary services within the traditional television sector is reserved for relatively few and big suppliers.

10.5.3. Positive Feed-back

It is very interesting to note, that while the laws of positive feed-back apply in many situations in competition between standards, the question of whether to transmit video via the television sector's infrastructure or the Internet also can be answered in more traditional ways. W. Brian Arthur's idea of increasing returns and positive feedback described on page 65f, rejects the traditional idea, where scarcity of resources leads to diminishing returns. While true in many standardisation scenarios, this does not apply to this particular case. The reason is that bandwidth in both systems is scarce – and if delivery of content via one system becomes too expensive, the suppliers will look for alternatives. It is therefore realistic that one possible equilibrium (instead of the multiple equilibria proposed by Arthur) exists in the balance between video via Internet and via the television sector's infrastructure.

⁴⁰³ The viability of such an approach is proven with the TVBoost service in the proof-of-concept prototype related to "The Hybrid Communication and Information Case Study".

Still, the forces of positive feedback do apply in other aspects, because the consumers have a benefit of joining the biggest among the systems. If, for example, television-type programmes delivered via the Internet remain few (as today, compared to the television sector), the number of viewers will be correspondingly small, leading to less incentive for internet-borne video among distributors. Thus, we have two counteracting forces at play, and will probably continue to have so, until either virtually unlimited bandwidth becomes available, which would eliminate the scarcity that is the original source of the mechanisms leading to diminishing returns.

10.5.4. Reverse Salients

The important reverse salient of lacking interoperability stands a reasonable chance of being remedied within the television sector. This is due to the possibilities opened up by digital television, where the addition of supplementary services is foreseen in the digital television systems. None of the digital television systems have however fully replaced the analog ones, and they will not do so for a couple of years. HDTV should fully replace analog broadcasts in 2007, and development is even slower in Europe. This means, that there is a span of years where the Internet based services of e.g. one-click recording⁴⁰⁴ and supplementary information has a good chance of establishing itself.

10.5.5. From Hardware-Software System to Communication Network

No matter whether an increase in interactivity takes place within the television sector or is offered by internet-based services, such a development would move the whole phenomenon of television information consumption in the direction from one-way to two-way communication. The most obvious form of two-way communication is the opportunity of viewers to request supplementary services. It can however also involve the communication between viewers⁴⁰⁵, and not only from viewer to distributor. This is an example of the many-to-many communication form presented in the Information and Communication Taxonomy chapter.

Lacking a return path, this has not been possible on traditional analog television, but with the addition of two-way communication (especially for the internet based solution, but also possible in the future forms of digital television), new opportunities of communication as opposed to mere consumption of information arise.

This in turn alters the ways, in which systems and standards compete. From being influenced by the indirect network externalities of hardware-software systems,

⁴⁰⁴ The integration of TV capture software and online TV guides into a one-click recording system has been demonstrated in the “The TVPC Case Study”.

⁴⁰⁵ The TVBoost service developed for “The Hybrid Communication and Information Proof-of-Concept Prototype” TVBoost had a chat facility, enabling viewers to exchange comments on the broadcast.

purchase decisions are now also influenced by the direct externalities of communication networks described by Katz & Shapiro on page 74 in the Theory chapter. Then, the size of networks becomes increasingly important, as the larger networks are more attractive to join than the small ones.

10.5.6. The Promise of Interactivity

There is no doubt that the future of television will be increasingly interactive. Whether this interactivity is a result of integration of Internet features or it will be developed within the new standards for digital television remains to be seen.

Another open topic is who or what, the viewer will interact with. Television has originally been one-to-one, one way communication. The various interactive services offered by broadcasters focus on altering this to a one-to-one, *two* way scenario. With proper inspiration from the communication forms observed on the Internet, *many-to-many*, *two way* interactivity might be realistic. It is clearly technically possible, but how this would suit the current bulk of TV programmes is another matter.

10.5.7. Path-dependence

Even though it can be claimed that television would have been more useful if it was capable of both-ways⁴⁰⁶, many-to-many communication, there is hardly support for a claim of 3rd degree path dependence in the case of television.

This is especially true, since the development of return paths in the television infrastructure and advanced input capabilities in TV sets would have made a much more complex system. Thus, there is no claim that an "opportunity of remedy" has been present at any time during the development of television. The television system is thus a case of 2nd degree path-dependence - the one in which the outcome may today be seen as regrettable, but no opportunity of remedy has been available.

If some degree of interactivity is not added to the television system in the future, a case of 3rd degree path dependence might be present. It is fair to say that the Internet provides the first "opportunity of remedy" of the reverse salient of lacking interoperability.

10.5.8. Installed Base

The lack of an "opportunity of remedy" is partly due to the rigidity of the infrastructure, partly to the installed base of TV sets. Most TV sets are not born with

⁴⁰⁶ Television is and has been widely intended as a one-to-many, one-way communication system for distribution of non-interactive information, though alternative perceptions originally were put forward, as described on page 5, under the "Early Conceptions of Television" header.

the capabilities necessary for interactivity. The computer – and hence the TVPC – is, but because such devices are not being widely used in typical TV scenarios of usage, the limited capabilities of current TV sets pose a hindrance to the development of interactive content.

Newer TV sets with interactive features, set-top boxes or TVPCs can solve this problem, but it implies a change of – or at least an addition to – the existing installed base.

10.6. Outlook

Much of the focus of this chapter is dedicated to the option of delivering supplementary services in forms and over an infrastructure characteristic of the computer/networking sector. Such a combination would keep the main content (e.g. the movie or the football match) in its original form: filmed moving pictures – only adding value to it by delivering additional value in the form of background information, one-click recording etc.

There are however initiatives pointing in the direction of further use of computer/networking methods. In the latest decades, many special effects in movies have been computer generated. Lately, some movie makers have gone all the way: movies such as “Ice Age”, “Shrek” and “Final Fantasy” have been produced without flesh-and-blood actors at all. While the two former are cartoon-style movies, Final Fantasy is photorealistic, and while still using actors for overlaying voices, it to a large extent eliminates many of the elements of traditional filmmaking.



Figure 52: Picture from Final Fantasy⁴⁰⁷ - a completely computer-rendered movie by Columbia Pictures.

Final Fantasy is rendered by the movie studio, and then turned into MPEG2 for distribution on DVD – or recorded to VHS. When played by viewers, it behaves like any movie – only the production process is different. An interesting future perspective is to have the rendering done by the viewer's appliance. This would mean that the viewer received a 3D model, much like the models in modern computer games. For such a concept to work, the 3D rendering capacity of computers would have to be above what is present in the average household computer of today.

At SIGGRAPH last year, we had a scene from the movie "Final Fantasy" for real time demonstration. We only marginally reduced the detail of the scene, a little less textures, a little less polygons - but it looked rather good, rather realistic. On a GeForce3, this scene ran interactively with something in between 12 and 15 frames per second. With the GeForce4, we were able to continuously run this scene with 30 frames per second. If looking a year into the future, I expect the real scenes from the movie to be hardware rendered in genuine movie quality.

Quote box 13: David Kirk, NVidia chief scientist about the possibilities of real time rendering of movies based on 3D computer models⁴⁰⁸.

⁴⁰⁷ Picture from The Internet Movie Database (online reference: http://us.imdb.com/EGallery?source=ss&group=0173840&photo=july2_19.jpg&path=gallery&path_key=0173840 – link active per 020627)

The quote above suggests that the idea is not too far fetched. Being an employee at graphics chip manufacturer NVidia, Kirk must be expected to be optimistic about his company's products. But it is important to note, that the graphics cards to which he refers are quite ordinary consumer products within the price range of common households.

One might ask what the benefit of this new form of movies could be. One clear benefit is the fact, that since the whole 3D environment from which the movie is rendered, is available, it is possible to choose camera angle. As is the case for 3D computer games, the movie could be rendered in stereoscopy, giving the viewer a perception of depth in the picture⁴⁰⁹. Depending on the level of detail, the 3D model on basis of which the movie is rendered could take up less space than a movie file – reducing the need for storage space and making network transfer (e.g. for "Video on Demand") a more viable solution.

Whether the artistic quality of the movie would satisfy the customers is another question. Complete computer rendering clearly excludes some of the advantages of movies (e.g. the ability of actors to interpret a role themselves), but on the other hand it gives an unparalleled flexibility with the design of settings and the appearance of characters.

Another example of substituting moving pictures with computer rendering has been developed by the Israeli company Orad, specialising in 3D modelling of sports events. The company offers a suite of soft- and hardware capable of generating 3D models based upon either analysis of 2D images or signals from transponders placed on the performers (e.g. football players or horses).

⁴⁰⁸ tecChannel website, 2002 – Own translation from German.

⁴⁰⁹ Stereoscopic video and 3D graphics is further explored in the "The Modality Case Study".



Figure 53: 3D rendered football match and camera position selection tool from Orad ToPlay⁴¹⁰.

The 3D model of track, players and movements takes up considerably less space than a video stream would do, because the only information necessary for the recipient to have the image rendered is the key coordinates of key elements such as the ball and the player's limbs. Hereby, sporting events can be transmitted to viewers with very low bandwidth consumption, even to mobile devices such as mobile phones and PDAs.

No appliances from the television sector have the rendering capabilities necessary to generate images as those presented in this section. Therefore, these forms of video are clearly suited for being viewed on computers. They can be stationary or handheld, connected via the cellular phone system or the Internet. As long as the appliance has sufficient processing power and the flexibility to have the necessary software installed, plus connection to an infrastructure over which to receive the necessary data, any innovation in this field can be introduced with relative ease.

⁴¹⁰ Orad website.

11.Synthesis

This chapter describes the approach of the concluding chapter and prepares the case study findings for conclusion. It explains how the empirical and theoretical parts of the dissertation are applied to answering the research questions. It furthermore condenses the sub-conclusions of the case studies and puts the findings of all case studies in relation to each of the elements of theory.

As mentioned in the “Research Questions in Relation to Empirical Studies” section, some case studies are particularly relevant to certain groups of research questions. This does not, however, mean that answers to the any one research question are sought in one case study only.

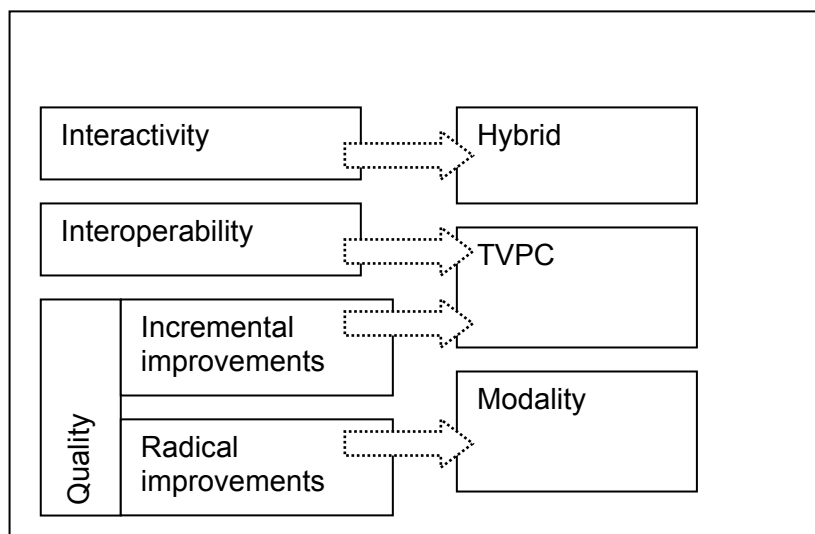


Figure 54: Linkages between "promises of convergence" and case studies. Dashed arrows indicate relations, but do not exclude alternative linkages⁴¹¹.

An alternative way to the “case study/research question” way of relating elements of this Ph.D.-project to one another is to explain a research question with a particular element of theory among those mentioned under the “Application of theory” header on page 98. This approach is likewise not applied in any strict sense. As is shown in Figure 55, there are no rigid linkages in the sense that one particular element of theory is expected to answer one particular research question.

⁴¹¹ This figure is a modification of Figure 5: Relations between promises of convergence and case studies.

There are, however, some research questions and theoretical elements that have obvious relations, some of which are exemplified with dashed block arrows. Such strict linkages are not defined, as it would imply severe restrictions upon the application of theory in an inductive study such as this. It would have been acceptable – and perhaps even necessary – if a deductive method were used.

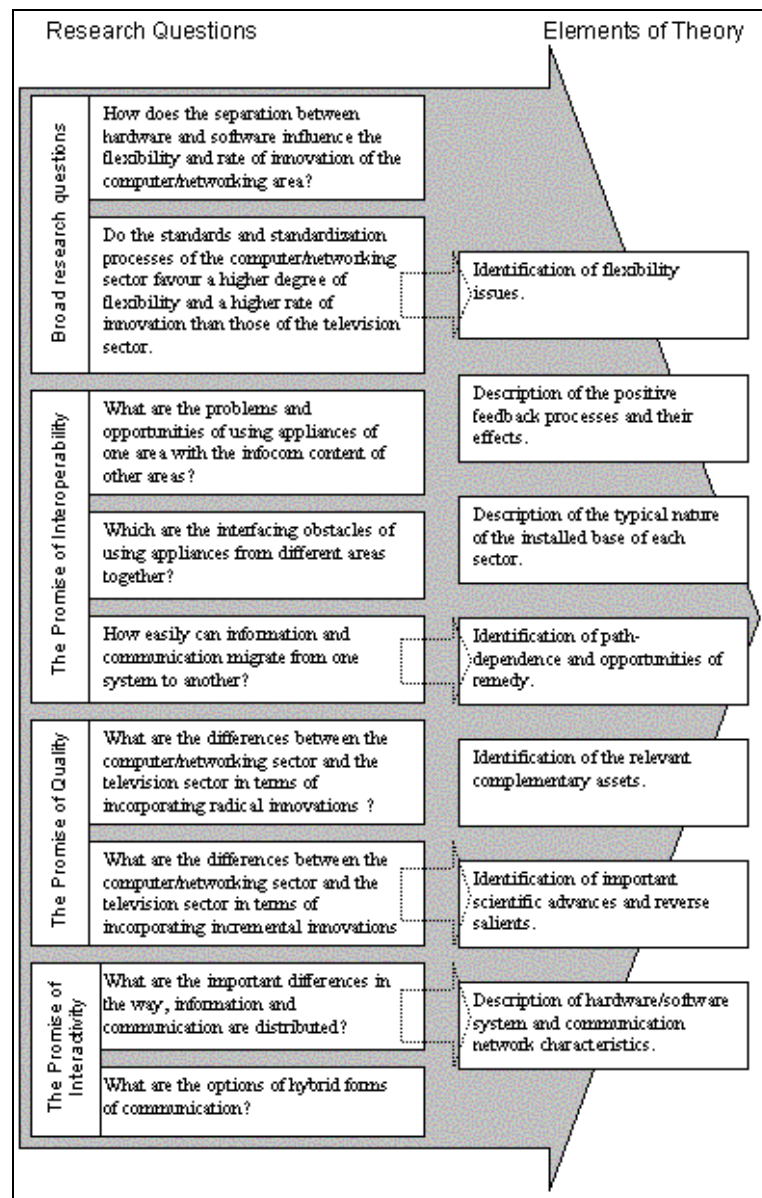


Figure 55: Research questions and elements of theory (Dashed arrows are examples of particularly obvious connections)

The overall conclusion is based upon a mix of looking at specific case studies and relevant elements of theory for each research question – combined with an overall perspective allowing a freer way of forming the conclusions, taking into account the partly exploratory nature of this project.

11.1. Sub-Conclusions of the Case Studies

This section contains the sub-conclusions drawn in the case studies, applied to each of the theoretic elements shown in Figure 55. For each theoretic element, the corresponding or conflicting observations are pointed out, and especially interesting findings are emphasized.

For each of the case studies, the findings presented in this section can be seen in the case studies' conclusions. The argumentation behind these findings is carried out earlier in the case study chapters.

11.1.1. Positive Feedback

None of the three cases display very powerful direct adoption externalities at present. This is primarily due to the fact, that none of the cases represent solutions for interpersonal communication. The externalities arising when the joining of a larger networks results in more people with whom to communicate, are not that obvious here. The best candidate case for direct externalities is stereoscopy, which could develop into an interpersonal communication system.

Still, positive feedback effects brought about by the indirect externalities are in force in all three cases, as a large number of users result in lower prices and greater product variety. This confirms the assumption that the whole area of convergence is subject to positive feedback.

11.1.2. Path-Dependence

The cases differ considerably regarding path-dependence. A case of 3rd degree path-dependence could be observed for interlaced scan, as U.S. and European NSOs and RSOs have decided not to make a switch to progressive scan mandatory. Also the 16:9 aspect ratio, which is widely regarded as superior to 4:3 has been introduced in the digital television systems – however still allowing for the 4:3 aspect ratio. In both situations, the standardisation organisations have made use of the opportunity of remedy brought about by the transition to digital. Allowing for the old and inferior formats can however be regarded as cases of 3rd degree path-dependence, as the simultaneous use of two formats might hinder transition to the newer and better ones.

The development of the television system into a one-way, one-to-many system is regarded as a case of 2nd degree path dependence, as no opportunity of remedy has

occurred until recently. If interactive features fail to be introduced in future television, a case of 3rd degree path dependence will be at hand.

No matter which particular degree of path-dependence, one can attribute to the cases, the opportunity of remedy is available. The convergence process and ongoing digitalisation make for a transition to superior formats and ways of communicating.

11.1.3. Installed Bases

The main obstacle to the transitions made possible by the “opportunities of remedy” described above, is the installed base of TV sets in private households. The rigidity of these appliances makes incremental innovations in quality impossible, resulting in rare, but significant switches in standards. This has been observed for all three case studies.

By contrast, the installed base of appliances of the computer/networking sector is of a nature that allows for implementation of incremental as well as radical innovations. Especially due to the distributed processing capabilities of computers, as well as the separation between hard- and software, alterations allowing for the use of new formats and standards are easily implemented.

11.1.4. Flexibility

The differences between the installed bases of the two sectors have profound implications for the flexibility of the systems. All three case studies confirm the assumption that computers are more flexible than the TV sector’s appliances in every important aspect. Furthermore, they support the idea, that this flexibility provides the basis for a much higher rate of innovation than in the TV sector.

In the ability of accepting incremental (e.g. a higher picture resolution) and radical (e.g. a stereoscopic image), the computer appliances display the necessary flexibility. It is furthermore able to accept all the signals, which are characteristic of traditional television viewing, and not being hampered by the purpose specific storage media of the TV sector, the computer is superior with regards to options and convenience of storage.

The infrastructure of the computer/networking sector (most prominently exemplified by the Internet) also allows for larger flexibility when accessing content and, being born as a both-ways, many-to-many system, allows for all the interactive services that the TV sector lacks. Furthermore, the low entry barriers of service providers allow for the computer/networking sector to offer a wide variety of innovative complementary services.

11.1.5. Complementary Assets

The TVPC and the Hybrid Communication and Information Case Study both show the importance of complementary assets. The options made available by the Internet allow for the offering of complementary, specialized, assets, which greatly add to the utility of new applications and appliances. The most prominent example of this is the online TV guides, which makes possible new ways of recording programmes.

In the case of modality, the computer/networking sector offers a much larger amount of potentially stereoscopic content. This is due to the fact that much of the content for computers – though not intended for stereoscopic viewing – easily can be converted to stereoscopy. By contrast, making of – or converting to – stereoscopy is a complicated task in the television sector.

The many options of offering complementary assets to an existing product or service make the computer/networking sector a fertile ground for a number of new business models, further stimulating innovation and development in this sector.

11.1.6. Reverse Salients

To identify indications of migration or switches of use from the television sector to the computer/networking sector, so called reverse salients have been identified in the case studies.

In the TVPC case, interactivity has been identified as a major reverse salient of the television sector – one that is not remediable for the foreseeable future due to the inherent one-way nature of the sector's infrastructure. Another reverse salient – the low quality in terms of resolution and refresh rate – is about to be solved in the U.S. with the new digital television standards, while the situation in Europe remains unchanged, as refresh rate and resolution for the time being are kept at the same level as the old analog standards.

In terms of appliances as well as infrastructure, the computer/networking sector stands a good chance of satisfying these needs, either by a combination of the two sectors or by a migration of television content to computer appliances and infrastructure.

11.1.7. Hardware-Software Systems and Communication Networks

Originally, the computer was developed as a pure hardware/software system without options of communication or information exchange. In the TVPC case, there is no indications that this is about to change. If used for real-time viewing and time-shifting of programmes, there is no exchange taking place between users, and hence no direct externalities. A widespread exchange of recordings between users could to some extent add a “communication network effect” to the TVPC, making the market favour

the most common storage format. There are, however, no indications that this is imminent.

Likewise, the modality case gave no strong indications of communication network characteristics, but the Hybrid Communication and Information case study revealed a number of indications of computers being used in communication network settings.

Nevertheless, the computer/networking sector is assuming the properties of a communication network rather than simply being a hardware/software system. This is, however, not as much due to the incorporation of communication phenomena from the other sectors, but rather due to its own communication forms such as Usenet, email, chat, etc. This will result in stronger externalities with the derived path-dependence and lock-in effect, creating at some point in time a situation where innovation and appearance of new services takes place at a slower rate than can be seen today. This does not necessarily influence the product development, as most hardware and software are independent of the services running on the computers.

This change leads to a new set of rules in the competition. As the direct externalities increase in influence, the importance of getting an early installed base upon which to build becomes increasingly important. Such a scenario would typically be characterised by a number of the strategies listed on page 82. One might also expect a larger proportion of open standards in the battles, as openness of a standard serves to attract supporters (as described on page 85) which is particularly important in gaining an early lead.

12. Conclusion

This chapter draws the overall conclusions of the Ph.D. project. It does not contain *all* the project's findings, as many are pointed out in the various sub-conclusions of other chapters. This chapter answers the research questions on the basis of sub-conclusions and the application of theory carried out during the work⁴¹². Finally, the chapter emphasises the important findings of this Ph.D.-project without relating them to any particular research question.

The conclusion verifies the hypothesis of the research problem on page 39. This is done through a step-by-step conclusion on each of the research questions derived from the research problem. Here, the conclusion claims that there actually is a higher degree of flexibility in the appliances as well as the infrastructures of computer/networking compared to those of television. It furthermore claims that this flexibility gives the computer/networking sector an advantage in adaptability as well as a higher degree of ability to stimulate the development of new products and services.

A discussion of the usefulness of the selected theory apparatus can be found in the Outlook and Discussion chapter.

12.1. Properties of the systems

The studies carried out in this project demonstrate, that a number of factors add to the flexibility of the computer/networking sector's appliances. Among these factors, the separation between hard- and software has proven to be of significant importance.

Computers consist of physical hardware, which is not easy to replace or upgrade. However, much of the functionalities of the computer are delivered by software, which can be installed easily – on the Internet it is often a question of a few minutes. Hereby, improvements to the appliances are very easily done compared to the television sector, whose appliances are mostly hardware-based, and where purchase of a new appliance often is necessary to enjoy recent improvements.

Not only in the case of smaller updates, but also when the computer is used for novel forms of infocom, the separation between hardware and software is crucial. The installation of e.g. a chat or email application does not imply purchase of new hardware. This is a property, which facilitates easy introduction of new services.

The flexibility described here applies not only to the “pure” computers (such as the TVPC), but also to the DVRs, which to a large extent are based upon traditional

⁴¹² This chapter draws upon the Synthesis chapter, in which the application of theoretic concepts to the findings is presented.

computer hard- and software. They can also be easily updated, however with less control – but also with less requirements of “computer literacy” - on behalf of the user. This leaves a large mass of potential users for the less flexible, but more easily manageable DVRs.

The flexibility and the low degree of path-dependence and lock-in brought about by the hardware-software dichotomy are crucial to the rate of innovation in the computer/networking sector. It is, however, also being introduced in set-top-boxes and other appliances closer related to the television sector, and the flexibility advantage of computers might not belong to this sector alone in the future. If the television sector adopts the hardware-software dichotomy, it will be a case of “true” convergence in the form, where one system adopts methods and configurations of another sector.

12.2. Standards and standardisation issues

The cases of computer/networking and television are classical cases of de facto vs. de jure standardisation. The computer/networking sector is characterised by multitudes of competing and alternative standards, made possible by the large degree of compatibility between the computers’ components. In the television sector, the standardisation processes are slower, but more thorough, showing consideration for the large installed bases of inflexible appliances.

The rate of innovation and succession of standards is considerably higher in the computer/networking sector. Here, users are seldom left stranded with unusable equipment as a result of the introduction of a new standard. These differences result in two contrasting paths of innovation or improvement, represented by a stepwise curve in the television sector and a smoother one in the computer/networking sector.

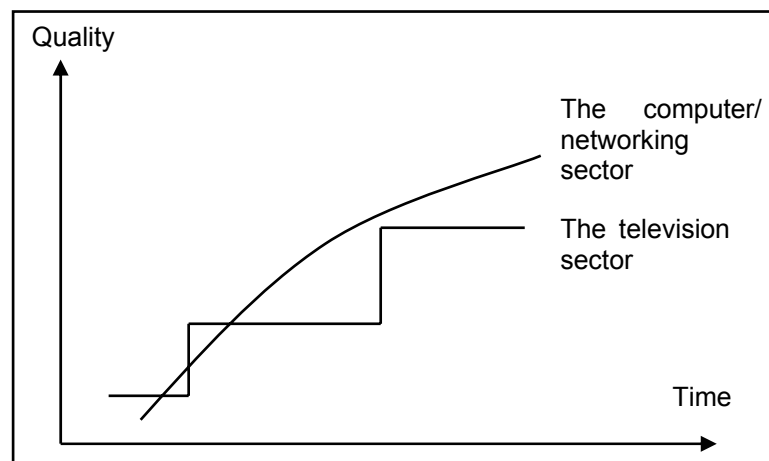


Figure 56: Innovation curves in the two sectors.

While the computer/networking sector is subject to the same standardisation globally, the television sector displays important regional differences. Compared to the U.S.A, the European DVB standard for digital television lags behind in terms of resolution and scan method. By maintaining the resolution and scan rate of current PAL and SECAM TV sets (a case of *backwards compatibility*), the current implementation of the DVB standard ensures, that the installed base of appliances remains usable. This consideration - as well as the fact that the European RSOs must base their decisions upon agreements between the member states - account for the less developed European digital television standard.

If, however, an improved high-definition standard is not introduced over the coming years, and the demand for such high-definition content is sufficient, there is room for the computer as the device on which to consume high-definition content such as D-VHS tapes or the proposed high-definition optical discs. Alternatively, the U.S. standard could be adopted in Europe, eliminating the separation into NTSC and PAL areas, which has lasted for decades. Such a step will, however, probably be subject to resistance from the content suppliers who have strong interests in maintaining geographical incompatibilities.

While being longer underway and imposing narrower restrictions than in the computer/networking sector, the standards of the television sector offer greater clarity than the multitude of competing standards in the computer/networking sector. They leave less to be decided by manufacturers and the market, and thus bypass the “natural selection” characteristic of the computer/networking sector. One can say that the SDOs, RSOs and NSOs of the television sector sacrifice innovation for stability. In an area characterised by national broadcasting corporations with public service obligations, this is hardly surprising, as the ability of all viewers to receive and view the content is of great concern.

12.3. Interoperability

The *promise of interoperability* has to do with the ability to communicate and consume information in ways characteristic of one sector on the appliances of another sector. When looking at television and computer/networking, this implies the use of computers for TV-related purposes and vice versa. This work mainly focuses upon TV content on computer appliances, not on computer content on TV sets.

The computer has proven to be fully capable of delivering television sector content. In many cases, it is able to exceed the traditional TV appliances in terms of quality and flexibility. The major drawback, however, is the current complexity and price of computers, at present relegating them to a role as enthusiasts’ devices and deterring less experienced users. This is likely to change, either through a development towards easier installable and configurable hard- and software, or by further development and adoptions of specialized TV-computers - so-called DVRs.

Not only is the computer able to undertake any task necessary in a television consumption process; it furthermore opens a wide array of additional opportunities. By allowing integration of online TV guides, the computer can be used for video recording purposes with an ease of operation unseen among traditional TV appliances. This also accentuates the opportunities of internet-based complementary services, which can be offered to TVPC users without the entry barriers characteristic of the television sector.

The flexibility of the computer allows it to utilize the latest innovations in video compression, hereby making it a very efficient recording device. Due to the multitude of available and flexible storage media, it offers much cheaper storage opportunities than the television sector with its relatively expensive and purpose specific storage media.

12.3.1. Cross-sector Information Consumption

Overall, there are no serious hindrances to the consumption of television content on computers. As described above, the computer is more than capable of this. A number of circumstances do however pose challenges to a seamless integration and thus act as obstacles to convergence.

First, the interlaced scan method characteristic of the old PAL, NTSC and SECAM systems as well as to DVB and some HDTV specifications are ill suited for being viewed on the progressive-scan computer display devices. This problem can be easily solved by software de-interlacing, but quality suffers marginally. Considering the wide adoption of the interlaced HDTV formats in the U.S.A., it is not likely that all future television will be in a progressive scan format.

Secondly, the television sector is moving towards 16:9 aspect ratio, a move that is not taking place in the computer/networking sector. Though 16:9 computer monitors have been introduced, it is not likely that they will rival the installed base of 4:3 monitors any time soon. The computer sector might be stimulated to a move to 16:9 by the many projectors becoming available in this format, but since most computers are used with smaller monitors, this is not likely to have any significant impact.

Even if traditional television content remains interlaced and computer monitors remain in 4:3 aspect ratio, these are insignificant problems with limited effect on the usability of computers as television consumption appliances.

12.3.2. Cross-sector Appliance Compatibility

Connecting the appliances of the two sectors is possible with any reasonably equipped TVPC. Apart from the benefit of a larger display, more suited for the traditional television usage scenario, the benefits of doing so are however limited. Due to the low

resolution and interlaced scan method of most television screens, the quality would suffer considerably compared to when viewed on a computer monitor or projector.

With the new U.S. HDTV sets capable of higher resolution and progressive scan, the perspective of connecting appliances across sectors is far more appealing. Often being equipped with a VGA input, these TV sets offer a picture quality approaching that of computer monitors. Finally, modern projectors and plasma screens are capable of displaying signals of computers as well as traditional TV appliances. This is in itself a convergence phenomenon, blurring the boundaries between television and computer/networking, as these display devices are not solely designed for one particular sector.

Both sectors are approaching one another by accommodating each other's interfaces. This is an indication of convergence, but it is not clear if it will be of the "migration type" (if e.g. the television sector moved towards using VGA only) or a more "true" convergence, either retaining a multitude of interfaces or agreeing upon a new future one such as DVI or component video⁴¹³.

12.3.3. Migration of content between sectors

At the appliance level, the potential for a migration of television content onto computers certainly exists, and is widely recognized by software developers and providers of complementary services. For it to become reality in a large scale, computers will have to become cheaper and easier to operate (e.g. in the form of DVRs), or the average level of computer literacy among users would have to increase significantly.

To put it simply, the choice of whether to use a computer or a TV set for TV consumption is a trade-off between on one hand the perceived flexibility and quality of computers, and on the other hand the low price and convenience of TV appliances. The point of switching for a potential user would be at the intersection of the graphs in the following figure.

⁴¹³ DVI emerges from the computer/networking sector and component video from the television sector, but both of the standards being fairly recent, they can be regarded as compromises between sectors.

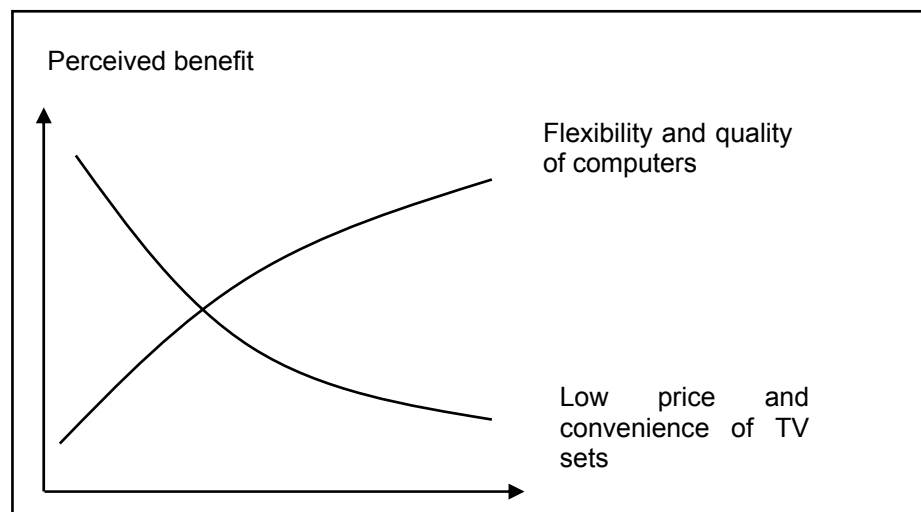


Figure 57: Point of switching between TV appliances and TVPC⁴¹⁴.

A complete migration would imply that the transmission of traditional television content moved to computer networks – most probably the Internet. This consideration is carried further in the “Interactivity” section.

12.4. Quality

The *promise of quality* has two sides to it. One is the incremental quality improvements in the form of e.g. an increased picture resolution. Another is the radical improvements in quality, which introduce fundamentally different ways of influencing the human senses.

12.4.1. Incremental Improvements

The quality capability of the TVPC (or any modern computer, for that matter) by far surpasses that of even the most advanced HDTV set. Not only is it flexible enough to accommodate virtually any sound and video format, its performance envelope is around twice that of a HDTV set in terms of resolution and refresh rate. It furthermore has the advantage of using progressive scan, a method which is widely agreed to be superior to the interlaced scan method of all analog and some digital television standards.

⁴¹⁴ It is not the ambition of this work to predict at what point in time this switch would occur, experience gathered with “The TVPC Proof-of-Concept Prototype” suggests that for the average user, it will not be before the year 2005.

Any computer is therefore future-proof in the sense that all present - and probably all imaginable - HDTV formats will be playable on it. While perhaps less important to a North American user, it is crucial to a European, who does not have the opportunity of purchasing high-definition appliances belonging to the TV sector. It can therefore be expected, that TVPCs will play a more important role in Europe, as they are ready to handle the expected high-definition pre-recorded media, and being prepared if or when high-definition broadcasts are initiated.

If more widely adapted, the TVPCs can provide an installed base for European high-definition DVB broadcasts, eliminating the chicken-and-egg problem of availability of suitable appliances, which discourages broadcasters from distributing high-definition content⁴¹⁵.

The flexibility and capability of computers provides a wide space of opportunity for content providers intending to use the Internet for distribution of high-definition content⁴¹⁶. This must be regarded as a likely scenario in case a future European HDTV standard turns out to be dissatisfactory⁴¹⁷ in terms of resolution, scan method and refresh rate. Here, a suitable appliance exists in form of the TVPC, and a content supplier would not have to worry about having an installed base of appliances available. The content provider would have great liberty in choosing the quality parameters of the content. A necessary precondition would be a considerably higher bandwidth than is available to common households today.

12.4.2. Radical Improvements

The studies of radical quality improvements have focussed on stereoscopy and the potential of the two sectors of delivering such content. The Modality Case Study indicates, that the most suitable appliance on which to consume such content is the computer. One reason for this is the flexibility and performance capability, which makes it easier to display the often demanding stereoscopic content. Another reason is the fact, that the 3D content in the form of computer games, simulations, virtual worlds etc. of the computer/networking sector is well suited for stereoscopic conversion. The computer/networking sector is hence free of the chicken-and-egg problem of lacking the incentive to produce content as long as no suitable appliances are available (and vice versa).

⁴¹⁵ For the coming years, this would be a very small installed base, but probably enough to serve a niche viewer segment.

⁴¹⁶ This is a "video on demand" scenario, which is frequently put forward.

⁴¹⁷ I.e. no content providers decide to use the higher resolutions in the DVB specification.

One could have expected, that the new digital television standards would provide the installed base on which to consume stereoscopic content, but unfortunately, the maximum of 50 and 60 fields per second (for HDTV respectively DVB) is insufficient to generate a flicker-free stereoscopic picture. Thus, this particular promise of quality is not likely to be fulfilled by TV sector appliances.

This leaves the computer/networking sector as the remaining potential driver of increased modality in the future information and communication landscape. It is, for two reasons, not likely to fulfil such a promise in the near future. Firstly because the suitable equipment for stereoscopic viewing in a living-room usage scenario is prohibitively expensive. And secondly, because the ease of converting computer content to stereoscopy does not affect traditional film production. Here, stereoscopic content has to be planned as such from the start of production – making it a complex and risky undertaking.

This leaves stereoscopy as an area whose biggest potential is the further development for computer related use. This is by no means an insignificant area, but it has little to do with convergence. Depending upon the price and capabilities of future display devices plus the movie industries' attitude towards increased modality, this can well change, but no strong indications of this has been found in the case study.

12.5. Interactivity

In its widest meaning, the *promise of interactivity* allows the consumer to choose what to consume as well as how and when to consume it. While interactivity has been an integrated aspect of computer/networking for a long time, it is only recently appearing in the television sector.

A major reason for the difficulty of introducing interactive TV has to do with the nature of the communication infrastructure and the way, in which the content is distributed. The Hybrid Communication and Information Case Study has identified a number of different categories of content, which are suited for different forms of infrastructures and distribution. This categorization indicates that some forms of infocom are suited for the Internet, while others are better suited for the traditional means of television distribution.

12.5.1. Sectoral Differences in Distribution

While the television system inherently is a one-to-one, one-way communication system, the Internet allows virtually any imaginable organisation of users. Most of the observed phenomena of interactive television suggest a one-to-one, *two*-way form of communication, allowing the users to interact with the TV station, but not with one another.

The major reason for the one-way characteristic of television has to do with the lack of a return channel in the distribution network. This has often implied the use of the telephone network for user feedback – a complicated and quite impractical solution.

The computer/networking sector, most prominently represented by the Internet, is inherently a two-way communication network, allowing many-to-many communication, and is furthermore able to deliver information upon the user's request, where the television system offers strictly real-time information. The former is not only convenient to the user, but also allows a service provider to receive information of the choices of consumers, thus allowing more well-targeted services and – in the final instance – contributing to the growth of the Internet.

The television sector has much to gain by incorporating the interactive possibilities of the Internet. With the adoption of cable modems, the cable TV infrastructure is in the process of readying itself for these possibilities. Terrestrial and satellite borne television is less prepared, and must be expected to rely upon alternative return paths for interactivity.

There is, however, also something to gain for the Internet by adopting the distribution methods of the television sector. Those types of programmes, which are geared towards real-time consumption by large groups of viewers, cannot efficiently be distributed by traditional unicasting. This would imply an immense load on the bandwidth, and would soon lead to congestion.

For the Internet to be a suitable infrastructure onto which all television content could migrate, alternative distribution forms such as multicasting must become widely available. The time horizon of such an addition to the Internet's capabilities is not clear⁴¹⁸, and until this is achieved, a suitable mix of information, communication and levels of interactivity must be sought elsewhere.

Not only the desires for interactivity presses towards such a change. The incremental as well as the radical quality improvements analysed in this project also suggest that consumers would be better suited with the flexible infrastructure of the Internet. In all cases, however, bandwidth is the limiting factor, and there is reason to believe that most television content will be distributed on the traditional television infrastructure in the foreseeable future.

12.5.2. Hybrid Infocom

Many speculations focus on *which* between the two systems is best suited for carrying interactive television on a general level, without considering the differences regarding the content of information or communication.

⁴¹⁸ An estimate on page 5 suggests that Multicast will be widely available in the year 2005.

An alternative perspective is integrating the strengths of both systems into a *hybrid* system, using the television broadcast infrastructure for real-time content to large viewer groups and using the Internet for delivering narrow-interest information at the users' request. One can say that such a development is well underway, as content suppliers choose where to distribute their content based on its nature. It has, however, not been implemented in settings, where the various forms of infocom supplement each other closely⁴¹⁹.

Such hybrid information and communication presupposes a very flexible appliance, either TV set with an Internet set top box or a TVPC. A suitable installed base of appliances on which to consume such information is not in place, and the potential customer base is small. Whether it will continue to be so in the future depends upon the development and adoption of TV appliances and distribution methods as well as DVRs and TVPC soft- and hardware.

12.6. Further Important Findings

This Ph.D.-project has identified a number of determinants of convergence, and has shown, that computers will play a major role in the future convergence scenario - perhaps not in the form of desktop computers, but embedded in future appliances.

The major reason of the expected massive influence of computers and computer networks is their flexibility. This flexibility is especially visible in the computer appliances ability to adapt to new formats and forms of infocom, as well as the computer networks' ability to facilitate virtually any form of communication and information consumption.

There are indications that the computer/networking sector is in itself developing towards a communication network rather than a staying a simple hardware/software system as defined by Katz and Shapiro on page 73. This points towards an increased positive feedback, further stressing the importance of a large installed base as described in the theory chapter.

It is certain, that the future will show thorough processes of convergence, in many ways altering the infocom landscape of today. What is less certain is whether this process will be in the form of migration (i.e. a move of information and consumption from one sector to another) or a "true" convergence (i.e. a mix of properties and capabilities of the two sectors' appliances or infrastructure). The most likely outcome in the foreseeable future is the "true" form, as bandwidth on the Internet is far from sufficient to serve the needs of all TV viewers. No matter which form the convergence

⁴¹⁹ An example of a close relation of television and Internet services are demonstrated in the MultiModality Proof-of-concept Prototype.

process may assume, it provides an opportunity of remedy of the regrettable cases of path-dependence observed in the television sector.

Among the three “promises of convergence” presented in this work, the promises of interoperability and interactivity are most likely to be fulfilled. The promises of quality – incremental as well as radical – are less likely to come true. This is due to the chicken-and egg-problem - as described on page 164 - of getting content when no or few suitable appliances on which to consume it, exist. Thus, the promises of modality and to a lesser extent interactivity depend upon the fulfilment of the interoperability promise - or more precisely the growth of the installed base of highly flexible appliances.

In overcoming the chicken-and-egg problem, complementary assets are crucial. Because complementary assets - especially in the form of content with increased quality - is much easier introduced in the computer/networking sector, the chicken and egg problem is much less pronounced in this particular sector. This is a driver towards the "migration" type of convergence rather than a "true" convergence, as the computer/networking sector is the only one with a sufficiently flexible installed base of appliances, and hence is the one, onto which future high-quality content would migrate.

Among the reverse salients - as described in the “Economics of Innovation” section in the theory chapter - that might lead to a change or a modification of the existing systems, the most important ones in the television sector are those of interactivity and quality. In a convergence perspective, the computer/networking sector is an obvious candidate for remedying these reverse salients. This can be in the form of a "migration" convergence as well as a more "true" convergence with future appliances containing elements of both sectors.

Among the parameters that contribute to the computer/networking sector’s influence on the future convergence process, the following are especially important:

- Flexibility due to hardware-software dichotomy allowing quick upgrades and easy adaptation to new functionalities.
- The highly flexible two-way infrastructure.
- Superior quality due to interlaced scan method.
- Fast and flexible standardisation.
- Easy provision of complementary services.
- Multi-purpose storage media giving flexibility in storage.

Also the television has a number of key strengths:

- Large display appliances are well suited for a “living room” usage scenario.
- Cheaper appliances.
- Appliances are easier to install, configure and use.
- Controlled standardisation.

Having described the characteristics and opportunities of the appliances and infrastructure of the computer/networking and television sectors, a number of further influential factors have been identified during the work of this project:

- The development of computer literacy of users.
- The future user-friendliness of hard- and software.
- Regulatory issues.
- The stance of IPR owners.

These factors are outside of the scope of this project, but nevertheless need being taken into account when attempting to predict the future paths of convergence.

It is not possible on the basis of this Ph.D. project to predict exactly how the process of convergence will progress. But this has never been the intention of this work. What the project does provide is an account of the properties and mechanisms taking place at the appliance and infrastructure level, viewed in a techno-economic perspective. In combination with other works focusing at other aspects of convergence, it will be possible with greater certainty to predict the outcome and give recommendations to those involved in the convergence process.

13.Outlook and Discussion

This chapter contains the considerations, which are outside the scope of the research problem and the discussion of the method used. They are concerned partly with the long-term perspective of convergence, partly with the approach of this Ph.D. dissertation.

13.1. Outlook

While this work has limited itself to focusing on the near future, there are a number of considerations relevant in a longer perspective. These have not been analysed in the main part of this dissertation, as they are of a somewhat speculative nature. Nevertheless, some interesting perspectives have been discovered during the work. They are presented here, without any particular argumentation.

Some case study chapters contain outlook sections. They can be read in relation to this section, but are maintained with the case studies, as they are more relevant to the analysis of convergence than the considerations presented below.

13.1.1. Content Sources

A major distinguishing property of the sectors involved in the convergence process is the *content* of information or communication. A news broadcast is very much a television phenomenon, as a website is an Internet phenomenon.

With the Internet, the access barriers to content provision are lowered significantly. Depending on the availability of suitable bandwidth, virtually anyone who has some content to offer has the possibility of getting it to the consumers. Not only new content providers have better opportunities. Also those who hitherto have relied on big TV channels to distribute their content (e.g. football leagues selling the right to broadcast tournaments to specific TV channels) can become content providers and distributors themselves. The future might therefore bring about a change in the ways in which content provision takes place, weakening the role of today's big media conglomerates.

Another important possible change is the 3D rendering of computer-made graphics, mentioned on page 241. This can lead to a totally different way of generating content. While it is not likely that viewers would want to see their favourite flesh-and-blood actor replaced by even the most brilliantly made computer rendering, a considerable niche for such content could well exist. Partly in the movie area as a sort of highly realistic cartoon, but perhaps even more as renderings based upon sports events as mentioned on page 244.

13.1.2. The Future Pace of Development

The computer might be superior to the TV sector's appliances as long as the pace of development is high, and adaptability is crucial. But if one imagines that at some point in the future (e.g. in twenty years), development slows down, (e.g. picture resolution settles at 16000 times 9000, which could be considered sufficient for all imaginable purposes) there will be less need for the flexibility that computers provide today. In such a case, stand-alone appliances will have an edge due to their relative simplicity.

The same is true for software. As long as new codecs appear, noticeably improving quality per unit of storage, it makes sense using a flexible appliance. Consider e.g. the quality difference of a MPEG1-VCD and a CD containing a DivX or WM8 based movie. When or if at some point in time, the speed of development decreases (the curve flattens), the benefit of going through the trouble of computers instead of a stand-alone, single-purpose appliance becomes marginal.

Such considerations might not be relevant at all. If or when the pace slows, computers might not be found in the form of today, as multi-purpose appliances. They might have become smaller and simpler to operate. They might be able to boot in less than a second, and they might be perfectly stable. In this case, the disadvantages of today's computers are eliminated.

The computers of the future might look nothing like those of today. They might well develop into cheap and specialized appliances for special purposes such as gaming, word processing, etc. They might to a great degree be imbedded into refrigerators, light bulbs and other objects. Calculating power might be located in one place, storage capacity in another, and all components might be able to communicate with each other.

In a scenario such as this, the separation of a computer/networking sector and a television sector will be a historic phenomenon.

13.2. Discussion

This section examines key areas of this work, and evaluates the success of the chosen theoretic approaches and the perspectives and concepts applied in this work.

13.2.1. Theory

The standardisation economy has been applied to many of the questions concerning the convergence process. This body of theory has proven useful in many respects, and the basic ideas of compatibility *standards* being *strong public goods*, as described by Kindleberger, resulting in *adoption externalities* and *positive feedback* - concepts promoted and accounted for by W. Brian Arthur - are fundamental to the economics of

standardisation These theories have proven to be a sound basis for the investigation of convergence between television and computer/networking.

The market's *tipping effect*, which has been described by W. Brian Arthur as well as Katz and Shapiro, has not been an important part of the theory apparatus. This is due to the fact that convergence, seen as an all-out war between the two sectors of television and computer/networking, has been shown not at all to be imminent. If, at all, it comes, it will not be within the first five to ten years. In such a situation, the market would be likely to tip, but it has not been seen as a likely near-future scenario in this work.

Based upon the above concepts, the theory of *path-dependence* introduced by Liebowitz and Margolis have served to explain many of the less-than-optimal situations that are observed in the television sector. While the distinction between 2nd and 3rd degree path-dependence focuses on whether an opportunity of remedy has been present, the important issue in this work is, that no matter which of the two degrees of path-dependence applies in a given situation, the opportunity of remedy is at hand, offered by the computer/networking sector.

The distinction between *hardware-software* systems and *communication networks* by Liebowitz and Margolis has proven to be of great value when looking at the basic characteristics and purposes of the appliances of the two converging sectors. This concept is inspired by Economides' and White's discussions of the characteristics of *one-way and two-way networks*. Considering the extensive discussions of the organisation of communication in this dissertation (the questions of real-time or not, one- or two way - especially in the light of interactivity issues) the Economides and White approach might have been more valuable than that of Liebowitz and Margolis. This is hardly an area of great concern, though, as the important parts of the two theories correspond.

Looking at the hardware-software system or communication network properties has been especially relevant when evaluating to which extent *direct externalities* are in play in the competition between systems. Had the focus of this project been on the convergence between telephony and computer/networking, it would have been even more crucial, because telephony is an arch typical example of a communication network. This work has been concerned with television rather than telephony, and – television being rather a hardware-software system with little direct externalities – the finding that the computer/networking sector is assuming communication network characteristics is of a somewhat dubious relevance. The fact is that it is not doing so by assuming the characteristics of the television sector, but rather by offering telephony-like services itself. This has nothing to do with the convergence between computer/networking and *television*, and the computer/networking sector's trend towards a communication network has little power in measuring how well it performs television services.

Still, the hardware-software-system/communication-network concepts have great power in explaining the nature of the converging areas. As has been observed, both sectors are hardware-software systems, which according to Liebowitz and Margolis exhibit *indirect* externalities. While less strong in effect than the direct externalities, they nevertheless have a significant effect. Plus, in some cases – e.g. when stored content is exchanged between users or private support networks become relevant – both sectors actually do assume communication network characteristics.

In competition between systems – and, as in this work – convergence between sectors, the *installed bases* of appliances are of great importance. While mostly used by Farrell and Saloner as a concept describing the shares of each competing system or sector, and thus as a measurement of relative power, the concept of installed bases has in this dissertation primarily served to explain drivers of or hindrances to convergence. Because of the inertia provided by installed bases, the flexibility of these bases has been a topic of great interest. There has not been an elaborate theory apparatus to apply to the findings, so the term has mainly been of descriptive value.

As described in this section – in relation to the tipping effect – the battle between the sectors has not really begun. Therefore, the *strategic issues* in standardisation have not been applied to any particular degree. There is, however, one exception, namely the concept of *complementary assets* introduced by David Teece as important strategic tools in a standards war. The all-important *content* that runs on the appliances of the two sectors is a crucial co-specialized asset. Also various online services (e.g. the online TV guides that integrate with TV tuner software) have proven to be important specialized asset. The major issue here is not how these complementary assets are applied as strategic tools in competition, but how the computer/networking sector is much more inviting to potential suppliers of complementary assets due to their lower entry barriers compared to the television sector.

Another strategic aspect, that has not been put to use in explaining the movements of market actors, is the distinction between *open and closed standards*. The role of these considerations has been limited to explaining certain features and approaches of Linux based TVPCs and DVRs and set top box operating systems.

Due to the complexity of the convergence process, Besen and Farrell's strategic concepts of "Tweedledum and Tweedledee", "Battle of the Sexes" and "Pesky Little Brother" have not been particularly useful in describing the convergence processes. This is mainly due to the fact, that the desire or intention of standards sponsors is decisive to the generic scenario in this model. However, it is not *standards* that converge, but *sectors*. And there is no CEO of the whole television or computer/networking sector to decide what the sector as such wants. We might, for example, define the convergence process as a "Pesky Little Brother" scenario, with the Napster community of the computer/networking sector wanting to be allowed to distribute and play movies, and the Hollywood movie studios of the television sector being hostile to such a proposal. But such a categorization makes little sense, as there are other actors in each sector than Napster and Hollywood, and it is impossible to make out one single viewpoint of each sector.

The field of Standardisation Economics is not new to me. I used a number of the concepts in my master's thesis, which focused on the battle between the VHS and Betamax video formats.

It has been a rewarding exercise to combine the well-known elements of theory with new ones from the same and other research areas.

In this Ph.D.-dissertation, I have had the challenge of applying a wider theory apparatus to a contemporary phenomenon, a somewhat different task than that of analysing a past process, but the theories have been up to the task and have been invaluable in deepening my understanding of the convergence process.

Author's comment 3: The contribution of Standardisation Economics.

13.2.1.1. The Supporting Theory

The economy of innovation has almost only been used as a source of concepts. It has been a good source, but this body of theory holds much explanatory power, that could have been applied with good success.

When examining the cases, it could for example have been relevant to identify in which of the *seven phases* described by Hughes (Figure 62 on page 352) the various developments are taking place. According to Hughes, different types of decision makers have varying degree on influence in the different phases. If the cases and phenomena of this work had been categorized in the various phases, it could have given indications as to which decision makers are in play. Such considerations have been left out of this project in favour of a more market and technology related focus, but it could have lead to interesting findings.

Also the economics of innovation could have contributed to the analysis. The *four critical factors*⁴²⁰ (presented by Dosi, and illustrated in the appendix in Figure 63 on p. 355) fit the focus of this project well, though this particular perspective is not applied on the analysis as such. Some of the four critical factors are particularly topical to this project, as any such identified critical factor can point to a change in future patterns of infocom, and in extreme cases lead to *paradigm shifts*. Therefore, each case study identifies the so-called “*reverse salients*”⁴²¹ mentioned on p. 352 (or “*unsolved difficulties*” in Dosi’s notion). The *scientific advances* are at the very core of this project and penetrate to each case study, where important innovations influencing the working of information and communication are described (implicitly in the case reports and without being specifically mentioned in sub-conclusions). The *economic factors* are examined with focus on standardisation issues, with the demand side represented in the considerations concerning market adoption and strategic issues. Among the *institutional variables*, this project also to some extent focuses on standardisation authorities, which are treated in a separate chapter: “New Standardisation Fora and Their Relationships with Traditional Standardisation Organisations” in the appendix. The identification of these four critical categories of factors could have given pointers towards future *switches* or *migration* of particular communication form onto other systems or the less revolutionary incorporation of methods and technologies of other systems.

Also the existing theories of information and communication have been abandoned in favour of a barebones taxonomy of information and communication. This is unfortunate in the sense that the “common language” between various research areas established by such theories is missed. The taxonomy has in itself proven useful in descriptive and conceptual terms, and has allowed this work to focus on certain aspects, but a model with more analytical power could have been useful.

Still, there has been no area of this study where any particular lack of theory has become obvious. Considering the immense proportions of a study mixing a wide array of theoretical approaches, a limitation of theory is necessary. The standardisation economy has proven to be quite sufficient within the focus of investigation, providing a good basis for later application of other theories.

13.2.2. Concepts

This Ph.D.-project has depended heavily upon concepts and definitions. In such a work, there is always a danger that the concepts, which are defined and developed not

⁴²⁰ These are the “scientific advances”, “economic factors”, “institutional variables” and “unsolved difficulties” (or “reverse salients”)

⁴²¹ An example of an actual reverse salient could be the delay of sound in IP-telephony or the limited resolution in PAL television.

quite cover the intended area. This danger has been sought avoided through elaborate definition and conceptualisation.

This work criticizes the common notions of television, telephony and Internet for not focusing on the crucial parameters. It suggests abandoning these terms in favour of parameters more precisely describing the information and communication. Nevertheless, terms such as “typical television content” or “typical computer appliances” appear repeatedly in this dissertation. This shows, that it is difficult to abandon these household terms, regardless of their tendency to confuse the analysis.

Here, the establishment of a concise taxonomy has been of great help. Even though the household terms are used for convenience and to facilitate understanding, the existence of a stringent framework of description has been an important conceptual basis of this project.

Two central concepts have been in focus throughout the work: Information and Communication. In order to achieve a more easily readable style, they have been combined into one word: Infocom. Another term, ICT (for Information and Communication Technologies) is much used, but this was not considered here because of the “T”. This work is not limited to looking at technologies; it also examines processes and organisation. These latter terms are not commonly associated with the term “Technology”.

One could argue, that there is no reason to speak of both information and communication, because information (or, rather, information *consumption*) simply is a special case of communication (a-one-way communication). These terms do, however, make sense intuitively, and they furthermore fit the theoretical perspective of “Hardware-Software Systems vs. Communication Networks” perfectly (with information being the content of the former and communication the content of the latter).

The perspective of three converging areas has proven usable in this work. At least, no particular problems of this perspective have become apparent. This can easily be due to the fact that the focus area is limited to looking only at two of the three converging sectors, resulting in a less complex focus area than if all three sectors had been involved.

Two other areas or sectors have, however, appeared as somewhat relevant to observe. One is the content providers (a.k.a. the intellectual property owners), who have considerable influence in relation to the chicken-and-egg problem of having suitable content to play on certain infrastructures and appliances. Their stance in issues as whether to transmit movies over the Internet or whether to keep interlaced scan, have influence on the convergence process. In this dissertation, they have been regarded as

belonging in the television sector, because their content (primarily movies, sports events and news) usually is watched on TV sets rather than computers.

Another area that might deserve being regarded as a separate sector is Hi-Fi (the area of radios, loudspeakers, amplifiers, etc.). Much of the development in audio quality - incremental as well as radical - has taken place in specifically within this area. As the content providers, it has been regarded as part of the television sector, mainly because of radio - where the appliance is manufactured by the Hi-Fi area, and content is delivered by the television sector.

It is questionable whether an alternative perspective on the converging sectors would have had any effect on the progress and outcome of this project. The reason is, that the detailed level of analysis has ensured that any phenomenon subject to investigation has been described in quite thorough terms. Hereby, the risk of generalisation by erroneously reckoning a given phenomenon among a particular sector has been avoided: even though e.g. Hi-Fi might deserve to be classified as an independent sector, the detail in which its appliances has been described, rules out any risk of arriving at a wrong result due to an erroneous classification.

13.2.3. Method

Depending on the purpose of the research undertaken, the researcher's academic background or philosophical inclinations, restrictions imposed by target groups as well as numerous other conditions, research can be carried out in a wide variety of fashions. The following sections put the methodological approach of this particular PhD-project into perspective, describe the alternative paths and explain why they were not explored. Finally, the usability of case studies and proof-of-concept prototypes – methods not particularly typical to a techno-economic study - is evaluated.

At first glance, a number of the components of this PhD-project can be recognized in some of the important research communities within the field of electronic information and communication. E.g. the presentation of future scenarios and description of their preconditions as well as the development of a taxonomy, are approaches typical⁴²² of the ITC program (mentioned on page 26) at Massachusetts Institute of Technology (MIT).

There are, however, other aspects of a research project than the outputs. One of the most basic of these is the purpose and the approach of a project. These aspects have to do with the incentive for doing research and the output, which is expected from the process.

⁴²² See description of the "ITC Research Methodology"
<http://itel.mit.edu/itel/rollovers/workplans.html#method>

13.2.3.1. One Among Many Approaches

The convergence between television and computers in this PhD-project has been conducted using an inductive and qualitative approach, based on multiple case studies, as described in the Research Design chapter at page 53. If one should attempt to classify the actual research method used in this project, a variety of definitions and classifications could be used. One among these is developed by Pertti Järvinen⁴²³, and defines six generic research approaches.

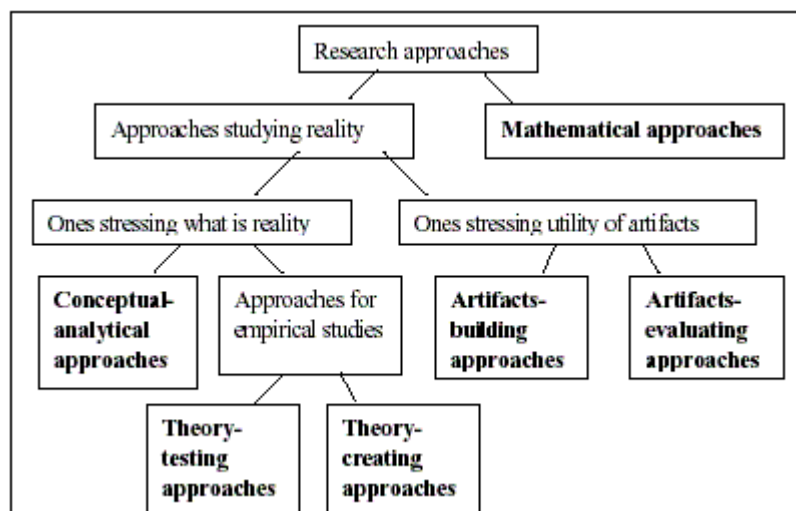


Figure 58: Järvinen's Taxonomy of Research Methods⁴²⁴

Within this methodology taxonomy, the approach of this PhD-project is mainly falls in the artifacts-evaluating category. It looks at the appliances, content and infrastructures of television and computer/networking, and evaluates their potentials with special emphasis on flexibility and adaptability.

To some extent, the project also has a theory-creating approach, in the sense that the work encompasses classification of phenomena (in the taxonomy on pages 101ff), and furthermore elaborates upon the existing theory used in the project. No new theory as such is proposed in this dissertation, but the dissertation contains a number of observations, which – elaborated further upon – could form the basis of new theories or extension of existing ones.

⁴²³ At the Department of Computer and Information Sciences, University of Tampere, Finland,
<http://www.uta.fi/~pj/>

⁴²⁴ Järvinen, Pertti: "On a variety of research output types"
<http://iris23.htu.se/proceedings/PDF/90final.PDF> (link active per 020116)

One example of this is the two different innovation curves in the two sectors⁴²⁵. Here, the effects of flexibility are described as resulting in a smoother curve of improvement in the computer/networking sector compared to the television sector. It is not elaborated upon to the extent that a new theory is nearby (one that e.g. states that “flexibility in hardware leads to a smoother and quicker development”), but it is an example of an observation that actually could inspire a new theory.

Also the extension of the “hardware-software vs. communication network” distinction by Katz and Shapiro with the chicken-and-egg considerations - the fact that the existence of appropriate hardware for new software to succeed and vice versa holds some potential - if not for a new theory as such, then probably for an important “concept”. Furthermore coupled to Teece’s “complementary assets” considerations as done on page 261, the chicken-and-egg problem appears as a promising theory concept, which could be subject to further considerations. The major reason that the chicken-and-egg problem has not been given more emphasis is, that it already being used: While not mentioned explicitly in Shapiro’s and Varian’s book⁴²⁶, Hal Varian has lately been using the term (e.g. in presentations⁴²⁷) since the publishing of the book.

Probably the best candidate for theory development is the hardware-software dichotomy identified on page 252. Apparently, the observation that a split into hardware and software is beneficial to flexibility and adaptability is novel. It is very much along the lines of thinking of Reed and Clark (co-authors of the articles on the end-to-end argument described on page 28) of placing functionality in the end notes (and thus perhaps not revolutionary), but still, it is an example of a potentially theory-creating aspect of this dissertation.

Among the “topics for further research” mentioned on page 277, are further considerations, which could have theory-building potential. The original intention of this PhD-project has however not been theory building as such, but – as mentioned earlier – more directed towards the investigation of properties of artifacts.

13.2.3.2. Alternative approaches

Not only regarding the purpose of research, but also from a more detailed perspective, a wide range of alternative approaches exist. Looking at the Research Design chapter at pages 53ff and the Method chapter in the appendix (page 338), there are a number of possible methodological choices, which differ from the ones applied to this PhD-project. In the following, these alternatives are described, and an account for the actual choice of this project is given.

⁴²⁵ Described on page 5

⁴²⁶ Shapiro and Varian, 1999.

⁴²⁷ An example can be found at www.inforules.com/powerpt/network.ppt (link active per 030212)

This project applies an **exploratory**, **descriptive** and to some extent **explanatory** approach to the convergence process. One important alternative approach is a **normative** one (i.e. a problem solving one) – but that is not the intention of the project, because the area of investigation (i.e. the convergence between television and computer/networking) is so new, that scientific efforts primarily should be directed towards exploration, description and to some extent explanation. From the outset, this was the aim of this PhD-project.

The approach of the product is **inductive** rather than **deductive** – meaning that instead of examining the world and suggesting relations and properties (the inductive way), it could have set out with the formulation of a hypothesis and then directed the scientific effort towards falsifying this hypothesis. But, the convergence process being an evolving and ongoing phenomenon, it would have been difficult to attempt this falsification, as one would need to look at the outcome of the processes involved in the reshaping of the information and communication landscape. These outcomes (at least, most of them) have not yet appeared. The subject of study is by no means at its final form, so claiming that “A leads to B”, and then looking to see if that is actually the case, would be futile.

A third alternative is a more **quantitative** approach - rather than the **qualitative** one applied. This would imply that instead of looking at the qualitative properties of information and communication phenomena, the approach would have been focused at e.g. the size of installed bases of competing formats and standards. One major problem here is, that such data are very hard to obtain. To evaluate e.g. whether TV-viewing on computers is progressing, one would have to obtain figures of TV tuner cards sold. Though this has been attempted during this work, it has been without success. This dissertation would admittedly have benefited from stronger quantitative evidence⁴²⁸. The validity of the argumentation, however, would hardly have benefited from a more quantitative approach, as the purpose of this project is not to describe the current and past status of competing systems, but to clarify which properties of these systems actually matter in the convergence process. Had a more quantitative approach been chosen, explanations of the ongoing processes and predictions of the future could have been based on e.g. sales figures. But again, this would be missing the whole aim of this project, as the intention is to answer questions of the “how” and “why” types, not the “who”, “what”, “where”, “how many” and “how much” questions⁴²⁹ – questions that are less relevant when explaining the techno-economic relations in the development of future information and communication systems.

⁴²⁸ - as is touched upon in the Empirical Evidence section at page 5.

⁴²⁹ The question types in various research strategies are further described in the appendix at page 5f.

13.2.3.3. The usefulness of case studies

The case study method probably isn't the first method that comes to mind when conducting a study on the interplay between technical and economic aspects of electronic information and communication. It is better known for being applied to anthropological studies and is widely regarded as belonging within the realm of the social sciences.

As described above, this study – though concerned with technical aspects – is not looking for hard and tangible facts on a particular technology or market. It is concerned with clarifying aspects of the converging systems, which have effect on the future development. Therefore, it is looking for explanations (as mentioned earlier, asking “how and why”) rather than hard facts and figures. For this purpose, the case study method is – though not being the only possible one – a widely recommended angle of attack⁴³⁰. The rationale behind this approach is described in further detail in the appendix' method chapter.

An obvious alternative to the multiple case studies of TVPC, modality and hybrid communication and information is a single case study. The subject of such a study might have been one particular artefact – e.g. TiVo or Xbox (described on pages 194f), but such an approach would have yielded less information on the “whole” process of convergence (not that the actual perspective does so – encompassing a “whole” process is hardly realistic in any case). The angle of attack choosing three cases, each of which is more than merely an artefact, probably has helped providing a better understanding of convergence in a larger perspective. A focus on one artefact, in turn, would have given deeper insight into the sociological, business-related and other aspects of one particular corner of the convergence process. One opportunity thus missed by the “larger” perspective is the chance to be close to the innovation and adoption processes. This approach could also have provided different kinds of empirical information in the forms of “interview” and “participant-observation” information as described by Yin on page 346 in the appendix.

As suggested above, case studies might not be the most straightforward choice in a project such as this. For a quantitative analysis, a survey-based approach could have been an alternative. This would imply e.g. a mapping of preferences and inclinations of users by use of questionnaires or interviews. This would have been a good approach had the focus of this work been more oriented towards e.g. usage scenarios. Here, the usability of various content and appliance types could have been assessed. However, with the more technology-oriented focus of this PhD-project, such an approach would have missed the point.

⁴³⁰ fodnote: Yin, 1994, p.

The choice of case studies is difficult to evaluate without being able to compare the outcome of this project to the outcome of one with the same mission, but with a different method. The case studies do however appear to have yielded the information and understanding necessary to answer the research problem and research questions of this project. Considering the aim of investigating flexibility issues within the three identified “promises of convergence”⁴³¹, the case studies illuminate these promises and the relevant issues well.

If one imagines that a different choice of cases would have lead to a different conclusion, this would have implied that at least one of the methods was improper for the purpose. This is one pitfall which is sought avoided by having thee case studies which – while shedding light on each their own area – turn out to collectively support the findings of this project’s conclusion. This does not ensure the validity of case study in a strict sense, but strongly suggests that the method has been appropriate.

13.2.3.4. The usefulness of Proof-of-Concept prototypes

Another among the above-described alternatives to case studies, especially applied within the natural sciences, is lab-based experiments. Had they been the sole source of empirics, obviously they would have told little about the workings of the markets. However, to supplement the case studies, corresponding experiments actually have been undertaken in this PhD-project.

These experiments are referred to as proof-of-concept prototypes, and are described further in the appendix of this dissertation. This approach is probably best known from development projects, where the purpose could be to convince investors or the management that a product or concept is actually feasible. To some extent, the proof-of-concept prototyping carried out in this PhD-project gives it properties, which it has in common with the EU IST projects mentioned on page 34. This PhD-project, however, is not concerned with developing a particular product or service, so one might inquire as to whether prototyping is actually relevant

Indeed, some of the case studies need no further proof. This is true for the TVPC as well as – though to a lesser extent - the Modality case study. No novel concept as such has been presented in the TVPC proof-of-concept prototype. On the contrary, the actual prototyping only focused on already proven solutions. The Modality proof-of-concept prototype failed in some respects, as it showed that no easy and affordable household stereo projection solution existed. As such, it rather served as a “proof-of-absence-of-concept” experiment.

The hybrid communication and information prototype, by contrast, actually proved the viability of combining television broadcasts with Internet-based html information.

⁴³¹ Described on page 5.

Though perhaps today seeming a bit trivial, at the time where it was developed, in early 1999, no similar solution was known⁴³². Still, considering that the purpose of this project is to clarify flexibility and adaptability characteristics of television and computers, the proof of the viability of this particular form of hybrid information and communication has little impact on the final outcome.

It is fair to say that the proof-of-concept prototypes have had little explicit value to this project – which accounts for their placement in the appendix. On the other hand, the implicit effects on the case studies have been valuable. The prototypes have served as a means of gathering the hands-on-experience that in turn has guided the collection of empiric information. They have helped accentuating the practical obstacles to the successful development and introduction of new forms of exchange of information and communication. It might not have been entirely correct labelling them as proof-of-concept prototypes considering only one out of three actually can be characterized as such, but in order to keep consistency, this particular term has been retained.

13.2.3.5. This Project's Approach

Many choices in this project could have been different from what is contained in this dissertation. The point of departure could have been different, the focus could have been on something other than appliances, content and infrastructure, the perspective could have been more demand-pull than technology-push and could have focused on the needs of consumers. Another methodological approach could have been used, had the intention of the project been another. Even with the same intention, another set of methods could have been applied. As is described in this section, the approach chosen reflects the fact that this project searches for explanations in an ongoing process.

The chosen methods have worked well within the chosen perspective. They have yielded results, which answer the research problem and its derived research questions. They have made it possible to explain the workings of a small fragment of a huge process, from one among a multitude of perspectives. Not being rigid as a deductive method would have been, it has allowed the search for explanations to be adjusted and guided by the findings as the work progressed – a feature which is very important when examining new and uncharted territory.

13.2.4. Empirical Evidence

Though the sources of evidence used in this work are both valid and informative, there are areas, where further evidence could be desired. For example, sales figures of 16:9 TV sets vs. 4:3 or TV tuner cards vs. TV sets could help substantiate the claims of a particular development. Often, such information has not been available, and estimates based on less strict sources have had to suffice.

⁴³² At least, not known to this author, in spite of extensive searches.

One particular area would have benefited from a survey. This is the claim of the influence of “private support networks” mentioned on page 77 is quite interesting, because it implies direct externalities in computer hardware-software systems. In this dissertation, this mechanism is claimed to exist without any particular support. Though this specific topic is of no crucial importance to the findings of this project, it would suit it well to have this claim substantiated. It would furthermore be an interesting finding by itself, if the influence of private support networks could be ascertained.

13.2.5. Topics for Further Research

During the work of this project, a number of research topics have appeared, offering themselves to further investigation. Due to the limitations in time inherent to this project, they are not included in the focus. These topics are presented in this section.

13.2.5.1. Incubators

When considering the fact that many new appliances such as the Microsoft X-Box is based on relatively traditional computer hard- and software, it could be interesting to examine, if the different pieces of TV-tuner software and services (such as DScaler and TVBoost) act as incubators for the stand-alone appliances. These software and services are primarily adopted by comparatively small user groups in which the concepts of software and service are tested and developed. According to the “incubator” idea, a concept is embedded in a stand-alone appliance when matured and proven viable on traditional TVPCs.

13.2.5.2. Critical Components

The economy of innovation presents topics such as Hughes’ “reverse salients” and Dosi’s “unsolved problems”. Dosi furthermore operates with the notion of “Scientific Advances”. When looking at technological systems in the computer/networking and television sectors, it is striking how some components are critical to the further development. They are not necessarily reverse salients or scientific advances (however they can become so if their development stalls or accelerates), but they tend to have an important determining influence upon the development of particular areas. Examples of such “critical components” are the TV tuner cards (making TV reception on computers possible) and the DLP projectors (making stereoscopy realistic in a living-room usage scenario). The role of such critical components could deserve special attention, as many explanations of a particular path of development could be found here.

14.Summary

“Converging Information and Communication Systems”

This Ph.D.-project investigates the process of convergence between television and computers. Identifying three “promises of convergence”: interoperability, quality and interactivity, the project examines the key properties of the computer and television sectors, which have had - or are expected in the future to have - significant importance to the process and consequences of the convergence. The project focuses on the appliances, i.e. the TV sets, the computers and their peripheral equipment. It also takes into account the infrastructure and signals, which contain and deliver the information and communication, as well as the nature of the content and the usage scenarios of consumers.

14.1. Promises of Convergence

The three promises of convergence are areas where computers show particular superiority over traditional television appliances:

- *Interoperability* is the ability of a system to provide and accept the services from another system. This has been observed to be a particular strength of computers, which – exemplified by their capability to play DVDs and record television programmes - over the years have evolved into devices rivalling those of the television sector.
- *Quality* is examined in two ways in this project. Improvements in quality can be incremental – meaning that consumers for example get a slightly improved display resolution. They can also assume more radical characteristics by profoundly increasing the modality of the content. This is seen in areas such as stereoscopic vision, where the computer by far has overtaken the TV set in terms of flexibility and quality.
- *Interactivity* has to do with the ability to influence the way that information and communication takes place. Not only its wide array of input possibilities makes the computer more interactive than a television set. Also the content and infrastructure is quite different in allowing for the user to choose how and when to communicate or consume information

14.2. Focus

The inspiration for the focus of the project is the fast development, which can be observed in the computer/networking sector. Partly reflected in the growth of the Internet, which over a few years has become able to deliver many of the services that have hitherto been available only in the traditional television sector. Partly reflected in

the ability of the computer appliances of handling a wider variety of content in higher quality than the traditional television sector.

The overall view of the project is centred on the standards that define the appliances and content. Here, comparisons of the television and the computer/networking systems are carried out, identifying key determinants of current and future development.

14.3. Theory

This focus presented above is reflected in the selected theory, the bulk of which comes from the area of economics of standardisation. The fundamental theoretic idea is the nature of *standards as strong public goods* with *adoption externalities*, described by Kindleberger. The main implication of this perspective is the existence of *positive feedback* and *tipping mechanisms* of the market; phenomena described by W. Brian Arthur.

Building upon the above concepts, the so-called *path-dependence*, described by among others Liebowitz and Margolis, is an important effect when explaining the static nature of the television sector. The appliances of each sector are looked upon as *communication networks* and *hardware-software systems*, as explained by Katz and Shapiro, a distinction that has to do with the fundamental properties and usage of a particular system, and the degree to which it exhibits direct externalities. The bulk of appliances are (according to Farrell and Saloner) described in the terms of *installed bases*, the inertia and flexibility of which serve to explain much of the convergence process.

To some extent, the strategic considerations of those involved in standards competition are included in the theoretic basis. This is especially the notion of *complementary assets* introduced by David Teece and the *openness/closedness* considerations of standards described by Shapiro and Varian.

In addition, supporting theory of innovation is involved for explanatory purposes. Especially the notion of *reverse salients* introduced by Thomas P. Hughes are put to use when describing a particular drawback or lack of the television sector which acts as a driver towards convergence.

14.4. Research problem

From the identified promises of convergence, a number of research questions are derived. They serve to guide the further investigation and - when answered in the concluding sections and chapters - to identify important properties of computers and television system. The fundamental intention of this is to explain how the future landscape of information and communication is influenced. These research questions are explored within a conceptual framework established on the basis of a number of

conceptual questions. This – combined with the lack of a suitable model of information and communication - has led to the development of a taxonomy within which the observed and analysed phenomena can be described by their fundamental characteristics.

14.5. Studies

To provide an empirical body, three technical cases are chosen for further investigation. They are – like the research questions – derived from the promises of convergence. A number of aspects are, however, common to the three cases, which is why a study of the underlying standards of the television and computer systems is carried out in a fundamental study. This study explores a number of comparable characteristics of the standards that define the interoperability, quality and interactivity properties of computers and TV appliances.

As it points out a number of general similarities and differences of the converging sectors, this chapter has important empirical value by itself, but its prime purpose is to explain the fundamentals of the building blocks of information and communication systems – i.e. aspects such as the signals, interfaces, storage media and display devices. The study is not limited to describing the particular standards, but also accounts for the standardisation processes leading to the actual standards. It concludes that – as to the fundamental properties - computers are more flexible and have a wider performance envelope in terms of quality than do the TV sector's appliances.

14.5.1. Case studies

Going more in depth with specific aspects, the three case studies examine the key issues of each of the promises of convergence. They are not case studies in the anthropological sense, as they focus on mainly technical issues.

14.5.1.1. TVPC

The first of the three case studies investigates the computer's ability to function in the roles usually performed by television sector appliances, and is thus related to the promise of interoperability. This includes capabilities such as receiving and displaying various forms of digital and analog television signals. The study also explores the television computer's (or TVPC's) ability to act as a video recording device, thus performing as a traditional VCR. Furthermore, the study investigates capabilities beyond those of traditional TV appliances, and finds that the integration with online television channel guides opens for great potential of the TVPC as a very capable and flexible recording device.

The chapter describes the various requirements of a TVPC and examines the hard- and software available to undertake such functions. It furthermore looks into a new breed

of appliances, the DVRs (Digital Video Recorders), which are based upon computer technology but function more as traditional television appliances, thus avoiding the complexity, which is the major drawback of the computer sector's appliances. This case study concludes that computer appliances are fully interoperable with the content and infrastructure of the television sector. It furthermore observes that while the computers are superior in terms of flexibility and quality – the former especially due to their inherent hardware-software dichotomy - they are still too expensive and complex to appeal to a wider audience.

14.5.1.2. Modality

The second case study examines the issues of modality – or more specifically, the ability of the TV sector's appliances as well as computers to process and display stereoscopic content. This is an important aspect of the quality promise of convergence, as it has to do with the appliances' ability to operate with the radical quality innovation of adding depth to the displayed image. This study presents an analysis of the available stereoscopic appliances and content, and accounts for the possibilities of a convergence process taking place.

The modality case study compares the stereoscopy aspects of the TV sector and computer/networking sector in terms of content and appliances. Apart from concluding that the computer clearly has the upper hand in every important technical aspect, the study identifies an important difference in the nature of content: While much of the entertainment content of computers is inherently suited for stereoscopic display, the television sectors stereoscopic content – which mainly consists of movies from the fifties – is subject to a chicken-and-egg problem, as there is no incentive among content producers to deliver stereoscopic content, as long as a suitable installed base of capable appliances is lacking.

14.5.1.3. Hybrid Communication and Information

The third case study focuses on the match between particular types of contents and the different infrastructures and transmission forms of the converging sectors. It examines the inherent capabilities of on one side the television sector's broadcast, one-way transmission and on the other side the unicast, two-way transmission of the computer/networking sector. It discusses the possibilities of delivering traditional television content via the Internet, and investigates the bandwidth constraints and possible solutions to it.

The study defines a set of important parameters of content, and identifies a number of hindrances (especially limited bandwidth and the inappropriate unicast structure) to the Internet as a short-term substitute of the television sector's infrastructure. It furthermore suggests a use of either type of network for what it does best: delivering content with a broad scope of interest and high importance of immediacy via TV

networks, and supplementing this with the more narrow-scope information with low importance of immediacy delivered via the Internet. A practical implementation of such a hybrid form of infocom is demonstrated in the case study's proof-of-concept prototype, where the Internet and the computer's capabilities are used for the interactive elements of content.

14.6. Conclusion

The project concludes that the computer/networking system is more flexible than the television system in a number of key areas, and that this flexibility benefit gives the computer/networking sector an advantage in the convergence process.

It is certain, that the computer/networking sector will act as a major driver of the convergence process. This is primarily due to its flexibility. This flexibility is a result of the separation between hard- and software (the so called hardware-software-dichotomy), which allows for rapid development and easy upgrading. Another major flexibility benefit comes from the inherently to-way infrastructure.

It is less clear in what form the computer appliances will influence the convergence process and take upon them roles as television appliances. It can either be in the form of desktop computers as we know them today, but alternatively, computer technology can be incorporated in new generations of small, easily operated appliances - exemplified in the so called DVRs.

Also the computer/networking sectors infrastructure - most notably the Internet - has the potential of supplementing the existing television infrastructures. Either by a complete migration of content onto the Internet or by a hybrid form of information and communication.

It is not possible at present to predict whether convergence will take place as "true" convergence - i.e. a mix of the two sectors, or in the form of migration - i.e. the computers and Internet taking over as the appliances and infrastructure for future television. In the shorter term of five to ten years, the latter scenario is quite unlikely, as there are a number of hindrances to it.

The uncertainties of the future development are due to factors outside the scope of this work, factors that can be accounted for by incorporating disciplines such as those mentioned under "future research".

14.7. Further Findings

Where the television sector first and foremost is a hardware-software system, the computer/networking sector is increasingly assuming the properties of a communication network rather than merely a hardware-software system. This is more

due to developments within this sector than to a convergence with the television sector. No matter what induces this development, it has an effect of the positive feedback that - according to the economy of standardisation - results in increased importance of having a wide adoption of one's system.

This - together with the identified chicken-and-egg problem of the interplay between content and appliances - accentuates the increased importance of the so-called complementary assets as strategic tools of promoting competing systems. Here, it is found, that the appliances of the computer/networking sector constitute a much more flexible installed base, capable of adapting to a much wider variety of new content.

Thus, the computer/networking sector is a potential candidate as a means to remedying the drawbacks (or, as they are referred to, the "reverse salients") of lack of interactivity and quality in the television sector. These reverse salients are to some extent results of the "locked-in" standards of the television sector, a static scenario in standards development brought about by the so-called 2nd and 3rd degree path-dependence, which has been characteristic of the television sector over the years.

The case studies emphasize certain dependencies among the promises of convergence in the sense that the promises of quality and interactivity depend upon the existence of a device offering the necessary interoperability. This device would have to be the TVPC described in the first of the case studies, as no television appliances are sufficiently suited to undertake the functions of stereoscopy and hybrid infocom.

14.7.1. Interoperability

Among the three promises, those of interoperability and interactivity are most likely to be fulfilled. The TVPC case study has demonstrated that interoperability is a reality, as the computer is able to process and display whatever form of television content the user could desire. A number of obstacles exist, such as the different aspect ratios and scan methods of the two sectors, but these are minor issues.

14.7.2. Interactivity

Interactivity can occur as improvements in the television sector alone, as the result of an adoption of the two-way information and communication form known from the computer/networking sector. This implies considerable infrastructure modifications, but the introduction of cable modem based Internet access is a considerable step in this direction. Interactivity in terrestrial and satellite based television depends on alternative return paths such as the telephone, and is not likely to be imminent. As an alternative to this "true" form of convergence, a migration of content onto the Internet is discussed, but due to bandwidth limitations, interactivity brought about by such a move cannot be expected until more efficient casting scopes than unicasting have been widely implemented.

14.7.3. Quality

The promise of quality improvements – incremental as well as radical – are highly dependent upon the availability of content. While the incremental quality improvements offered by computers to some extent can be utilized by the U.S. HDTV standards, there is still ample room for an increase in picture resolution. This tendency is even more pronounced when examining the options of radical quality improvements. In spite of the fact that the computer is a highly flexible device, capable of displaying stereoscopic video of a quality by far exceeding that of existing TV sets, the lack of stereoscopic television content makes a convergence process in this particular area somewhat unlikely. There are strong indications that stereoscopic use of traditional computer content will increase, but this is a development taking place in this particular sector alone, having no influence on convergence as such.

14.7.4. Flexibility

Though not all promises of convergence are certain to come true, the computer/networking sector has - and is expected to continue having - profound influence on the convergence process. The main reason is the flexibility of this sector, partly due to the hardware-software dichotomy, partly due to the infrastructure, which with its two-way architecture is inherently interactive.

14.7.5. Standardisation

A number of other factors add to the computer/networking sector's strength. Having a tendency towards de facto standardisation, the sector allows numerous solutions to a particular need. This leads to a more complex market in which many standards wars take place, and though contributing to a fast rate of innovation, it also creates a less transparent market to consumers as well as suppliers. Here, the slower, but more thorough standardisation processes of the television sector's organisations provide clarity at the cost of speed. This is reflected in the different appearances of the "development graphs" of the sector. While the computer/networking sector develops smoothly, with small, but frequent improvements, the graph of the television sector displays few, but large steps.

14.7.6. Entry Barriers

The openness in standardisation of the computer/networking sector is paralleled by the low entry barriers of potential service providers. This contributes to the variety in supply, and while adding further to the growth of this particular sector, it also makes the proposed hybrid communication forms an obvious solution to the television sector's interactivity needs, as the interactive elements of information and communication easily can be delivered by 3rd party suppliers.

14.7.7. Advantages of the TV Sector

The preceding sections have described an impressive number of strengths of the computer/networking sector. The television sector, however, also has a number of advantages, ensuring that they – at least for the near future – will prevail. First of all, the traditional television appliances are relatively simple to install, configure and operate. Secondly, they are cheaper than the computers. Thirdly, they are developed specifically for the purpose of information consumption in a “living room usage scenario”. Especially their large display surfaces make TVs suited for being viewed by larger groups. This can also be obtained with TVPCs, but at a considerably higher price. While the prices of projectors and large plasma screens undoubtedly will drop over the coming years, it will surely take a while before TVPCs become widespread household appliances. The DVRs stand a better chance, as they are developed with the specific purpose of interconnecting with traditional television appliances.

14.7.8. Geography

There is a considerable geographic difference in the potential of computer technology based appliances in general and TVPCs in particular. While the U.S. have an existing supply of HDTV content as well as TV sets, the European DVB standard offers no particular quality improvement in its present implementation. Therefore, the TVPC has a more obvious gap to fill in Europe, provided, of course, that suitable content in the form of future high-definition DVDs or the recently introduced D-VHS tapes becomes available in Europe.

14.8. Future Research

While this project has given a thorough account of the influential techno-economic factors of the convergence process, a number of issues have been identified, which are likewise important, but outside the scope of this work. There are a number of research areas such as the psychology of users, regulatory and intellectual property issues and strategic considerations of content suppliers, which have not been part of this work. This partly calls for further studies of key areas, partly for collaboration with scholars from other research areas.

15. Dansk Resume (Danish Summary)

”Konvergerende Informations- og Kommunikationssystemer”

Dette Ph.D.-projekt undersøger konvergensprocessen mellem TV og computere. Det identificerer tre ”løfter” eller perspektiver som konsekvens af konvergens: Interoperabilitet, kvalitet og interaktivitet. Desuden undersøger det nøgleegenskaber ved computer- og TV-sektorerne, som har haft – og i fremtiden forventes at have – væsentlig indflydelse på processerne i - og konsekvenserne af - konvergens. Projektet fokuserer på apparaterne (de såkaldte ”appliances”), d.v.s. fjernsynsapparater, computere og deres periferiudstyr. Det inddrager også infrastrukturer og de signaler, der indeholder og leverer informationen og kommunikationen. Endvidere undersøges kommunikations- og informationsindholdets grundlæggende natur samt forbrugernes anvendelsscenarier.

15.1. Konvergensens Løfter

De tre ”løfter” er områder, hvor computere udviser særlig overlegenhed i forhold til traditionelt fjernsynsudstyr.

- *Interoperabilitet* er evnen hos et system til at levere og operere med services fra et andet system. Dette har vist sig at være en særlig styrke ved computere, som – eksemplificeret ved deres evne til at afspille DVD’er og optage TV-programmer – over de senere år har udviklet sig til at kunne konkurrere med TV-sektorens apparater
- *Kvalitet* er undersøgt på to måder i denne afhandling. Forbedringer i kvalitet kan være inkrementelle – d.v.s. at forbrugerne f.eks. opnår en lidt bedre billedopløsning. De kan også antage mere radikale former, ved gennemgribende at forøge modaliteten af indholdet. Dette kan observeres på områder såsom stereoskopi, hvor computeren er langt foran fjernsynet hvad angår fleksibilitet og kvalitet.
- *Interaktivitet* har at gøre med evnen til at bestemme, hvordan information og kommunikation finder sted. Det er ikke kun det store udvalg af input-muligheder, der gør computeren mere interaktiv end fjernsynet. Også indholdet og infrastrukturen er væsentligt anderledes, da den tillader brugeren at vælge hvordan og hvornår, kommunikation eller informationsforbrug skal finde sted.

15.2. Fokus

Fokus for dette arbejde er inspireret af den hastige udvikling, der kan observeres i computer/netværkssektoren. Dette afspejles dels i Internettets vækst, da det i løbet af få år er blevet i stand til at levere mange af de services, som hidtil udelukkende har

været tilgængelige i den traditionelle fjernsynssektor. Dels afspejles det i computerapparaternes evne til at håndtere en bredere vifte af indhold i højere kvalitet end i den traditionelle fjernsynssektor.

Projektets generelle perspektiv er centreret omkring de standarder, der definerer apparater og indhold. Her foretages der sammenligninger af computer/netværks- og fjernsynssystemer, og den nuværende og fremtidige udviklings vigtige determinanter bliver identificeret.

15.3. Teori

Ovenstående fokus afspejles i den valgte teori, hvoraf hovedparten kommer fra området omkring standardiseringsøkonomien. Den grundlæggende teoretiske ide er, at standarder er *stærke offentlige goder* med *adoptionseksternaliteter*, beskrevet af Kindleberger. Den vigtigste konsekvens af dette perspektiv er eksistensen af *positiv feedback* og *"vippe"-mekanismer* på markedet; fænomener beskrevet af W. Brian Arthur.

Den såkaldte *vej-afhængighed*, beskrevet af blandt andre Liebowitz og Margolis, bygger på ovenstående koncept. Vej-afhængighed er et vigtigt element, når man skal forklare fjernsynssektorens statiske natur. Apparaterne i hver af de to sektorer (fjernsyn og computer/netværk) bliver betragtet som *kommunikationsnetværk* og *hardware-software-systemer*, som beskrevet af Katz og Shapiro. Dette er en skelnen der vedrører de basale egenskaber og den grundlæggende anvendelse af et givet system – samt i hvilken grad den udviser *direkte adoptionseksternaliteter*. De mange apparater, der er i anvendelse er (som angivet af Farrell og Saloner) beskrevet i form af *installerede baser*, hvor disses inertie og fleksibilitet har stor forklarende kraft i forhold til konvergensprocessen.

I nogen grad er de strategiske overvejelser hos de aktører, der delager i konkurrencen mellem standarder, inddraget i teoriapparatet. Det gælder navnlig de såkaldte *komplementære aktiver*, et begreb introduceret af David Teece, samt spørgsmålet om *åbenhed eller lukkethed* i standardiseringsstrategierne – beskrevet af Shapiro og Varian.

Med henblik på yderligere uddybning inddrages desuden innovationsøkonomiske teorier. Særlig begrebet *"reverse salients"*, introduceret af Thomas P. Hughes, anvendes med henblik på beskrivelse af særlige ulemper eller mangler ved fjernsynssektoren – mangler, der kan fremme og yderligere stimulere konvergensprocessen.

15.4. Problemformuleringen

Afledt af konvergensprocessens identificerede løfter præsenteres et antal forskningsspørgsmål. Disse fungerer som retningslinier for de videre undersøgelser og – når de besvares i de konkluderende afsnit og kapitler – bidrager til identifikationen af centrale egenskaber ved computere og fjernsyn, samt til forklaring af den indflydelse, der udøves på det fremtidige informations- og kommunikationslandskab. Disse forskningsspørgsmål undersøges inden for en konceptuel ramme, der er etableret på basis af et antal konceptuelle spørgsmål. Dette har – sammen med manglen på en egnet model af information og kommunikation – ført til udviklingen af en taksonomi, indenfor hvilken de observerede og analyserede fænomener kan beskrives med udgangspunkt i deres grundlæggende egenskaber.

15.5. Studier

Empirien i Ph.D.-projektet udgøres af tre tekniske cases. Disse er – ligesom forskningsspørgsmålene – afledt af konvergensens tre løfter. Flere aspekter ved de tre case-studier er ikke desto mindre fælles, hvorfor en grundlæggende undersøgelse af computer- og fjernsynssystemernes standarder foretages. Her undersøges et antal sammenlignelige karakteristika ved de standarder, der definerer interoperabilitets-kvalitets- og interaktivitetsegenskaberne ved computere og TV-apparater.

15.5.1. Case-studier

De tre case-studier går yderligere i dybden med undersøgelse af særlige aspekter, der er afgørende for opfyldelsen af de tre løfter. De er ikke case-studier i antropologisk forstand, da de fortrinsvis fokuserer på tekniske forhold.

15.5.1.1. TVPC

Det første casestudie undersøger computerens evne til at fungere i rollen som fjernsyn, videooptager, o.s.v., og har som sådan forbindelse til løftet om interoperabilitet. Dette omfatter egenskaber såsom evnen til at modtage og vise forskellige former for digitale og analoge TV-signaler. Studiet undersøger også fjernsyns-computerens (eller TVPC'ens) evne til at fungere som videooptager. Desuden undersøges det, hvilke muligheder TVPC'en kan tilbyde, som de traditionelle TV-apparater *ikke* kan, og konstaterer, at der er stort potentiale i at integrere TVPC'en med on-line TV-oversigter, hvilket bl.a. gør TVPC'en til et meget kapabelt og fleksibelt optageapparat.

Kapitlet beskriver de nødvendige krav til en TVPC, og analyserer den tilgængelige nødvendige hard- og software. Desuden undersøges en ny type apparater, de såkaldte DVRs (Digitale VideoRecordere), der er baseret på computerteknologi, men fungerer og ser ud som almindelige apparater fra TV-sektoren (som f.eks. satellit-set-top-bokse eller videobåndoptagere). Disse typer af apparater besidder ikke den kompleksitet, der

er en væsentlig ulempe ved computersektorens apparater. Case-studiet konkluderer, at selv om computerne er overlegne m.h.t. fleksibilitet og kvalitet – det førstnævnte grundet deres indlejrede hardware-software-dikotomi – er de stadig for dyre og komplicerede til at appellere til et bredt publikum.

15.5.1.2. Modalitet

Det andet case-studie undersøger forhold omkring modalitet – eller mere specifikt, fjernsyns- og computersektorens apparaters egnethed til at behandle og fremvise stereoskopisk indhold. Dette er en vigtig del af kvalitets-løftet, da det har at gøre med apparatets mulighed for at operere med den radikale kvalitetsinnovation, som det er at tilføje dybde i billedet. Studiet præsenterer en analyse af de tilgængelige stereoskopiske apparater og det tilgængelige indhold, og redegør for mulighederne af en konvergensproces på dette område.

Modalitets-casestudiet sammenligner forhold omkring stereoskopi i fjernsyns- og computer/netværkssektoren hvad angår indhold og apparatur. Udover at konkludere, at computeren er førende på stort set alle vigtige områder, identificerer studiet en vigtig forskel hvad angår indhold: Mens meget af underholdningssoftwaren til computere er ”født” med muligheden for stereoskopisk fremvisning, er der i forbindelse med det traditionelle indhold i fjernsynssektoren (f.eks. film og nyheder) tale om et ”hønen-eller-ægget”-problem, idet en manglende installeret basis af apparater til afspilning og fremvisning gør, at indholdsproducenterne har ringe incitament til at producere stereoskopisk indhold.

15.5.1.3. Hybrid Kommunikation og Information

Det tredje case-studie fokuserer på sammensætningen af bestemte typer af indhold og på de forskellige infrastrukturer og transmissionsformer, der findes i de to konvergerende sektorer. Det undersøger de indlejrede kapabiliteter hos på den ene side fjernsynssektorens broadcastede, envejstransmission, og på den anden side computer/netværkssektorens unicastede tovejstransmission. Det diskuterer mulighederne for at levere traditionelle fjernsynsudsendelser via Internettet, og undersøger begrænsningerne i båndbredde og disses mulige løsninger.

Studiet definerer et sæt af vigtige parametre for indhold, og identificerer et antal hindringer (især begrænset båndbredde og en uhensigtsmæssig unicast-struktur) for, at Internettet på kort sigt kan substituere fjernsynssektorens infrastruktur. Det foreslår i stedet brugen af hver type af netværk til det, den er bedst til. D.v.s. levering af indhold med en bred appel og som generelt gerne ses live via fjernsynets infrastrukturer – og tilsvarende indhold med en snævrere appel, og som kan konsumeres på et hvilket som helst tidspunkt via Internettet. En praktisk implementering af en sådan *hybrid* information og kommunikation er demonstreret i case-studiets ”proof-of-concept”-

prototype, hvor Internettet og computerens egenskaber er anvendt til de interaktive indholdselementer.

15.6. Konklusion

Projektet konkluderer, at computer/netværkssystemet er mere fleksibelt end fjernsynssystemet på et antal nøgleområder, samt at denne fleksibilitetsgevinst giver computer/netværkssektoren en fordel i konvergensprocessen.

Det er utvivlsomt, at computer/netværkssektoren spille en vigtig og dominerende rolle i konvergensprocessen. Dette skyldes først og fremmest dens fleksibilitet. Denne fleksibilitet er resultat af opdelingen mellem hard- og software (også kaldet hardware-software-dikotomien), der tillader hurtig udvikling og let opgradering. En anden væsentlig fleksibilitetsgevinst skyldes infrastrukturen, der er "medfødt" tovejs.

Det er mindre klart, i hvilken form computerapparaterne vil påvirke konvergensprocessen, og på hvilken vis de vil fungere som fjernsynsapparater. Det kan enten finde sted i deres nuværende form som "desktop"computere, eller alternativt kan computer-teknologien indkorporeres i de nye generationer af små og letbetjente apparater - eksemplificeret ved de såkaldte DVR'er.

Ligesom apparaterne, er computer/netværkssektorens infrastruktur - navnlig Internettet - et potentielt supplement til de eksisterende fjernsyns-infrastrukturer. Enten i form af en fuldstændig flytning af indhold til Internettet, eller som hybride former for information og kommunikation.

Det er umuligt for nuværende at forudsige hvorvidt konvergens vil finde sted som en "ægte" konvergens - d.v.s. at der sker en sammenblanding af apparater og infrastrukturer fra de to sektorer, eller om der vil blive tale om "migration" - d.v.s. en fuldstændig flytning af indhold fra fjernsynssektoren til computer/netværkssektoren. På kort sigt - d.v.s. de kommende fem til ti år, er det sidstnævnte scenario usandsynligt, da der eksisterer en del hindringer.

De usikkerheder, der vedrører den fremtidige udvikling, skyldes faktorer, der ligger uden for dette projekts fokus; faktorer, der kan redegøres for ved at kombinere resultaterne i dette arbejde med andre forskningsdiscipliner som f.eks. de, der er nævnt under "Fremtidige Forskningsområder".

15.7. Yderligere Resultater

Hvor fjernsynssektoren først og fremmest er et hardware-sofwaresystem, antager computer/netværkssektoren i stadig højere grad karakter af et kommunikationsnetværk snarere end udelukkende at forblive et hardware-sofwaresystem. Dette skyldes snarere indre udviklinger i sektoren end en konvergens med fjernsynssektoren. Uanset

hvad denne udvikling skyldes, har det en virkning på den positive feedback, som – ifølge standardiseringsøkonomien – resulterer i en øget betydning af udbredelsen af et givet system og en øget magt til et i forvejen udbredt system.

Sammen med ”hønen-eller-ægget”-problemet i forbindelse med samspillet mellem indhold og apparater understreger dette forhold den øgede vigtighed af de såkaldt komplementære aktiver som strategiske værktøjer i konkurrencen mellem standarder. Her viser det sig, at apparater fra computer/netværkssektoren udgør en meget mere fleksibel installeret basis, der er i stand til at tilpasses sig en meget bredere vifte af nyt indhold.

Derfor er computer/netværkssektoren et godt bud på et middel til afhjælpelse af de ulemper (også kaldet ”reverse salients”), som udgøres af fjernsynssektorens mangel på interaktivitet og teknisk kvalitet. Disse ”reverse salients” er nemlig i nogen grad resultat af fjernsynssektorens fastlåste (eller ”locked-in”) standarder – en fastlåst situation, der skyldes den såkaldte anden og tredje grads vej-afhængighed, som har været karakteristisk for fjernsynssektoren gennem tiden.

Case-studierne understreger visse afhængighedsforhold mellem konvergensens forskellige løfter således, at løfterne om kvalitet og interaktivitet afhænger af tilstedeværelsen af et apparat, der tilbyder den nødvendige interoperabilitet. Dette apparat ville formentlig i givet fald være TVPC’en, som er beskrevet i det første af de tre case-studier, fordi der ikke eksisterer fjernsynsapparater der er i stand til at varetage funktioner som stereoskopi og hybrid information og kommunikation.

15.7.1. Interoperabilitet

Blandt de tre fremførte løfter, er løfterne om interoperabilitet og interaktivitet dem, der med størst sandsynlighed bliver opfyldt. TVPC-case-studiet har vist, at interoperabilitet allerede er en realitet, idet computeren er i stand til at behandle og fremvise stort set en hvilken som helst form for fjernsynsindhold, man måtte ønske. Der findes visse hindringer såsom de forskellige højde/breddeforhold på film og andet indhold samt forskellige scanmetoder i de to sektorer, men det er mindre problemer, der let kan afhjælpes.

15.7.2. Interaktivitet

Interaktivitet kan fremkomme som forbedringer alene i fjernsynssektoren, som resultat af en adoption af de tovejs informations- og kommunikationsformer, der findes i computer/netværkssektoren. Dette forudsætter betragtelige ændringer af den eksisterende infrastruktur, men introduktionen af internetadgang via kabelmodem er et betragteligt skridt i denne retning. Interaktivitet i jord- og satellitbaseret fjernsyn afhænger af alternative returveje som for eksempel telefonen, og er næppe realistisk i den nærmeste fremtid. Alternativt til denne form for ”ægte” konvergens diskuteres en

fuldstændig flytning af fjernsynsindhold til Internettet, men på grund af begrænsninger i båndbredde er dette scenario lidet sandsynligt. Nye metoder til transmission såsom Unicasting kan afhjælpe manglen på båndbredde, men en sådan metode er ikke tilstrækkeligt veletableret for nuværende.

15.7.3. Kvalitet

Løftet om kvalitetsforbedringer – inkrementelle såvel som radikale – afhænger i høj grad af, at der eksisterer indhold, der besidder tilsvarende kvaliteter. Hvor de inkrementelle kvalitetsforbedringer, computeren tilbyder, kan udnyttes af de amerikanske HDTV-standarder, er der ikke desto mindre et stort uudnyttet potentiale i computeren. Denne tendens er endnu mere udtalt når man ser på de radikale kvalitetsforbedringer. På trods af, at computeren er et særdeles fleksibelt apparat, der er i stand til at fremvise stereoskopisk video af langt højere kvalitet en eksisterende fjernsynsapparater, udgør manglen på stereoskopisk indhold – først og fremmest film – en voldsom hindring for konvergens. Der er stærke indikationer af, at anvendelsen af stereoskopi på computere vil tiltage, men denne udvikling vil foregå alene i computer/netværkssektoren og har som sådan ingen indflydelse på konvergens.

15.7.4. Fleksibilitet

Selv om ikke alle konvergensens løfter med sikkerhed bliver opfyldt, har computer/netværkssektoren – og vil formentlig fortsat have – gennemgribende indflydelse på konvergensprocessen. Den vigtigste grund hertil er den fleksibilitet, sektoren udviser. Dels grundet hardware/softwaredikotomien, dels grundet infrastrukturen, som med sin to-vejs-arkitektur er medfødt interaktiv.

15.7.5. Standardisering

En del andre faktorer bidrager til computer/netværkssektorens styrke. Med sin tilbøjelighed til de facto-standardisering tillader sektoren et stort antal løsninger på et givent behov. Dette fører til et mere komplekst marked, hvori mange standard-krige finder sted. Selv om dette bidrager til en høj innovationsrate, medfører det også et mindre gennemslagskraftigt marked – for forbrugerne såvel som for leverandørerne. Her medfører fjernsynssektorens langsommere – men også grundigere – standardisering en større klarhed på bekostning af innovationsraten. Dette afspejles i de forskellige fremtoninger af sektorernes ”udviklingskurver”. Hvor computer/netværkssektoren udvikler sig glidende, med små, hyppige forbedringer, fremviser kurven for fjernsynssektoren få, men store skridt.

15.7.6. Adgangsbarrierer

Den åbenhed, der karakteriserer standardiseringen i computer/netværkssektoren modsvares af de lave adgangsbarrierer, der møder potentielle serviceudbydere. Dette

bidrager til variation i udbudet, og stimulerer yderligere sektorens vækst. Derudover lader det de foreslåede hybride kommunikationsformer fremstå som oplagte løsninger til fjernsynssektorens interaktivitetsbehov, da de interaktive informations- og kommunikationselementer med lethed kan tilbydes af tredje parts udbydere.

15.7.7. Fjernsynssektorens Fordele

I de foregående afsnit er en række overvældende fordele ved computer/netværkssektoren blevet præsenteret. Ikke desto mindre har fjernsynssektoren også sine fordele. Det er fordele, der sikrer, at fjernsynssektoren – i det mindste i de kommende år eller årtier – vil bestå. Først og fremmest er de traditionelle fjernsynsapparater forholdsvis lette at installere, konfigurere og betjene. Dernæst er de billigere end computere. For det tredje er de udviklet netop med henblik på det ”dagligstueagtige” anvendelsesscenario, som fjernsynsindholdet lægger op til. Særlig deres store skærmarealer gør fjernsyn velegnede til at blive set af større grupper. Dette kan ganske vist også opnås med en TVPC, men til en betydeligt højere pris. Selv om priserne på projektorer og plasmaskærme utvivlsomt vil falde i de kommende år, vil det tage nogen tid før TVPC’er forefindes i de mange hjem. DVR’en har en bedre chance, da den er fremstillet netop med henblik på at kunne fungere sammen med eksisterende fjernsynsapparater.

15.7.8. Geografi

Der er væsentlige geografiske forskelle i potentialet for computerbaserede apparater i almindelighed og TVPC’er i særdeleshed. Hvor de Forenede Stater har adgang til at købe færdige HDTV-apparater og –indhold, tilbyder den europæiske DVB standard ingen betydelige kvalitetsforbedringer i sin nuværende implementering. Derfor er der i højere grad behov for TVPC’er i Europa – forudsat, selvfølgelig, at tilsvarende indhold, for eksempel i form af høj-definition DVD’er eller de nyligt introducerede D-VHS-bånd bliver tilgængelige i Europa.

15.8. Fremtidige Forskningsområder

I og med at dette projekt har redegjort for de tekno-økonomiske faktorer, der øver indflydelse på konvergensprocessen, har det blotlagt visse forhold, der ligeledes er vigtige, men som falder uden for projektets fokusområde. Der er således et antal forskningsområder såsom brugerpsykologi, regulatoriske og ophavsretlige forhold, samt indholdsleverandørernes strategiske overvejelser, som ikke har været del af dette arbejde. Dette lægger dels op til yderligere studier af nøgleområder, dels til samarbejde med forskere fra andre discipliner.

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Appendix

The appendix contains a number of sections that are not sufficiently topical to be included in the main body of the dissertation. They are, however, relevant as they supplement and elaborate upon main chapters of the dissertation.

“New Standardisation Fora and Their Relationships with Traditional Standardisation Organisations” is a paper presented in year 2000 on the Communicate2000 conference, written by Anders Henten and Alexander Oest, CTI. (co-author statement by Anders Henten is included).

“The Shaping of Television” is a report written in 1999 by Alexander Oest in a Ph.D.-course, 67495 History of Technology at the Technical University of Denmark

“Method” contains further considerations around the methodological approach of this work. This chapter goes into more detail than the descriptions in the main part of the dissertation.

“Economics of Innovation” gives deeper explanations of the relevance of a perspective based upon the theories of technological systems, paradigms and trajectories. These theories are mainly used for descriptive purposes in this work, which accounts for their placement in the appendix.

The three proof-of-concept prototypes, each supporting a corresponding case study, can also be found in the appendix:

- The TVPC Proof-of-Concept Prototype
- The MultiModality Proof-of-concept Prototype
- The Hybrid Communication and Information Proof-of-Concept Prototype

They are not part of the main body of this work, as many of the findings during the prototyping and experimenting can be found in the case studies.

The appendix also contains “Suggestion for stereoscopic adapter for LCD type projector”, which is a specification developed during the MultiModality Proof-of-concept Prototype work. The feasibility of the concept was tested by DTU students Troels P. Rørdam and Maja Nordhild, in a mid-term project supervised by Erik Dalsgaard at Department of Physics. As their work concluded that the concept was technically sound, it was found to be too complex and expensive to be of any practical

use⁴³³. This path was therefore not explored further, and is therefore not to be found in the main body of the dissertation.

Finally, the appendix contains a list of figures and tables.

⁴³³ Rørdam & Nordhild, 2001.

New Standardisation Fora and Their Relationships with Traditional Standardisation Organisations

Paper for:
Communicate2000
Category: Global Convergence.

by

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Introduction

By the turn of the millennium, a process prophesied a decade earlier is well underway. This process is the coming together of various forms of electronic communications, often referred to as the *convergence phenomenon*. This implies that communication forms, which before were separate, interweave at various levels. Current research mainly focuses on three - until recently distinct - communication forms in this process. These are Television/Mass Media, Telephony and Computers/Networking. Technologies such as cable modems and IP-telephony are examples of convergence phenomena combining technologies of different sectors at different levels.

Being communication networks, the converging sectors have traditionally been subject to extensive standardisation. The television/mass media and telephony sectors are characterised by inherent and well-established standardisation traditions with a number of standardisation organisations, some of which have existed for many years. Alternatively, the computer/networking sector is a considerably younger system with standardisation processes, which differ in many ways from the older sectors.

With the ongoing convergence process blending the technologies of various sectors into new communication systems, one can wonder how standardisation will take place in the future landscape of communication.

The topic of this paper is the past and current standardisation traditions (or paradigms or regimes) of the converging sectors and the possible directions for future standardisation of converged communication technology. The paper will provide an overview of the trends in the converging sectors and give pointers to possible future development of standardisation processes in the converged media. It will furthermore describe the different standardisation considerations of the involved players.

Procedure of the paper

The paper sets off by defining the fundamental concept of standards and proceeds by describing generic forms of standards (de facto and de jure) and various ways for standards to emerge.

Then, the generic players (government, users, companies etc.) involved in the standardisation processes of communication networks are presented. Their considerations underlying standardisation are identified and explained. Furthermore, a number of main generic areas of communication standardisation are identified. This serves the purpose of clarifying the reasons and rationales of the various players.

Finally, a synthesis of the identified development and standardisation trends of the converging landscape is made, providing a basis for prediction of future standardisation regimes.

Standards - definitions

In electronic communication, a standard can be defined as an agreement between some (but not necessarily all) players in a certain field where the topic of agreement is the technical specifications of various aspects of the communication technologies.

Often a distinction is made between so-called *de jure* and *de facto* standards. This distinction relates to the emergence of standard - basically whether they emerge as a result of the specifications of a national or international authority or as the outcome of market introduction of a standard leading to the establishment of that particular standard.

For further detail, distinctions are made between sponsored and unsponsored *de facto* standards. Sponsorship implies that one or more market players (often companies organised in so-called consortia) promote the standard. Similarly, *de jure* standards can be defined by the level of support they have through legislation. A mandatory standard is imposed on market players by law.

| De Facto | De Jure |
|-----------------|----------------|
| Sponsored | Mandatory |
| Unsponsored | Voluntary |

Figure 59: De facto and de jure standards

Generic players and agendas in standardisation

In the creation of standards for electronic communication, a number of fundamentally different players are involved. These players interact with one another to a certain extent and at various levels. The various players have different aims of their involvement and different means of influencing the process. Within the various converging sectors of electronic communication, the interplay between the actors in standardisation varies considerably.

These differences in standardisation tradition and the clash between them as various areas converge is a central area of interest of this paper. But before moving to describe actually operating players, a presentation of the various generic types of players and their interests and agendas would be in place. This chapter describes the differences

between the various types of actors in standardisation processes. Hereby a basis for description of work processes in different standardisation organisations is provided.

Suppliers and manufacturers

Manufacturers of equipment are central players in standardisation. In order for a given communication system to actually function, availability of the appropriate hardware is a precondition. It is fair to assume that the equipment manufacturers' main purpose of participating is the possibility of influencing the standardisation process in their favour. The harvest of participating in standards development will typically (assuming the standard in question becomes successful) be in the form of added knowledge of the standard that becomes generally accepted, sharing of information with other participants in the standardisation process, and – perhaps foremost – reaping the harvest of intellectual property rights embedded in the standard.

Not only the manufacturers of the specific pieces of hard- or software, subject to standardisation, come into play in the game of standardisation. Also suppliers of so-called complementary assets have an interest in - and in some cases influence on – the outcome of the process. In the battle of video recorders, for example, it proved crucial to the outcome that VHS had a larger base of pre-recorded tapes in video shops than Betamax had.

Government agencies, ministries etc.

Government agencies and (semi-) public players are often more or less evidently involved in de jure standardisation processes. Their incentive must be presumed to be first and foremost the public benefit.

However, a possible conflict between various views on the public benefit can be illustrated by the weighing of national versus regional interests. National or regional agencies often give the benefit of their specific nation or region priority over the benefit of others⁴³⁴.

Users

Users are in many cases anonymous - and left to expect the government agencies and non-governmental organisations to represent their interests in standardisation processes. However, the standardisation traditions of some areas are more inclined to involve users in the standardisation process. Especially in the case of pure market driven standardisation, the choice of users (in their property of buyers) has great

⁴³⁴See e.g. Jayakar, referring to Raymond Akwule, "Global Telecommunications: The Technology", Administration and Policies 113-120 (1992)

bearing on the outcome of competition between different standards. Users as individuals have practically no means of influencing the standardisation processes. Obviously, they have the liberty to support the standard they might prefer through purchase, but due to the lock-in and feedback effects of standardisation markets, they have little influence except for in the early introduction phase.

With the coming of the internet with its distributed intelligence and software based communication systems, the lack of user influence is changing. The entry barriers to new product and service suppliers are being reduced significantly. Obviously, consumer habits can be hard to change, but numerous other barriers can easily be overcome.

User influence can also be achieved by forming user groups participating in the standardisation work of those standardisation organisations interested in involving users in the standardisation process. This, however, calls for another type of user - one that has the sufficient dedication to actually become involved in standardisation work.

Standardisation Organisations

As the central aim of this paper is describing the various types of standards developing fora, a presentation of four different forms of standardisation organisations is given. The three first mentioned mainly operate within the field of de jure standardisation. They are categorised by their geographic scope ranging from national to global.

SDOs

SDOs (or standards development organisations) have in the case of ITU for more than a century been formally developing global (or at least international) standards thus minimising the need for governmental regulation. Among these large organisations are the International Telecommunication Union (ITU), the International Organisation for Standardisation (ISO⁴³⁵) and the International Electrotechnical Society (IES).

RSOs

A type of organisations resembling the SDOs is the regional standards organisations (RSOs). As the name of this generic form of standardisation player implies, RSOs aim at developing standards for a certain geographic region rather than for the entire globe. The regional focus of the RSOs can partly be seen in the light of the previously mentioned governmental inclination to favour their own region's benefit.

⁴³⁵ Note that ISO is not an acronym; instead, the name derives from the Greek word *iso*, which means equal.

Examples of RSOs are the Standards Committee T1 of the United States, the Japanese Telecommunications Technology Committee (TTC), and the European Telecommunications Standards Institute (ETSI).

NSOs

At a yet lower regional level we define the NSOs – the National Standardisation organisations. These strictly national standardisation organisations often assume the role of representing users. As the RSOs, they often contribute to the standardisation development of the SDOs.

Consortia

Consortia (or fora or standards related organisations - SROs) are groups usually formed by industry players. The aim of consortia are often short sighted and centered around the development of a specific technology or service (for example Bluetooth and WAP).

They differ from SDOs by their lack of accreditation from an independent government related body.

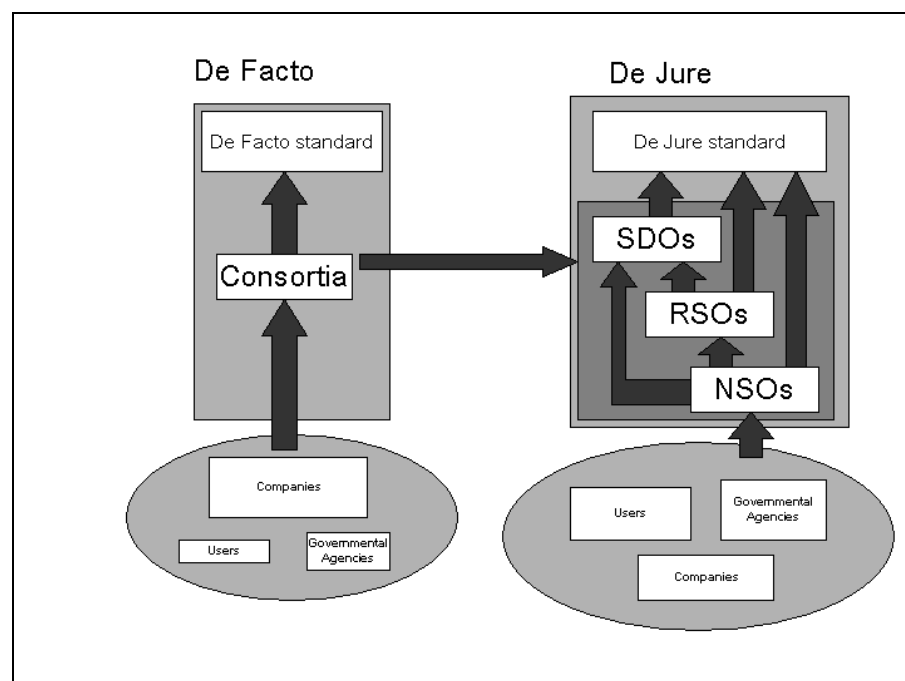


Figure 60: Influences in standardisation

Figure two shows the current landscape of standardisation influence. We observe two columns based on the de facto/de jure distinction. The arrows illustrate the flows of influence from various actors in the standardisation processes. Clearly, the segmentation of consortia as a commercial actor tool and de jure standardisation organisations as giving more way to users' influence remains. But as we have touched upon before, the picture can be changing in favour of a more direct user influence based on actual use of the offered products and services.

The horizontal arrow going from consortia to the box of SDOs, RSOs and NSOs illustrates that some consortia standards are being adopted as de jure standards.

Trends in standardisation of converging communications

As has been indicated in the previous, today's converging electronic communication is reflected by profound changes in the standardisation traditions. We are moving from an ordered landscape of few and well-known players - mostly the well-established SDOs and RSOs into a turbulent world of emerging, competing, winning and losing standards. Electronic communication in its many forms is no longer solely defined by established players offering one single system for a particular form of communication. This is, to a large extent, due to the rise of computer/networking communication - in particular driven by the internet.

Flexibility

If one should identify a single cause for this shift, a good candidate is the inherent flexibility of the terminal equipment - the computer. Compared with TV sets, radios, telephones and fax machines, the computer is able to adjust to virtually any communication form or service. The computer of today is prepared for the addition of further in- and output devices such as microphones, webcams, etc. At the technical level, an introduction and adoption of a new service often only necessitates download of the appropriate piece of software onto the communicating parties' computers -plus relatively easy installation of whatever additional hardware necessary for the communication process.

Furthermore, the establishment of wide area computer networks and, additionally, the conversion of existing networks (primarily cable television) to be able to transmit both ways increase the options of communication. Finally, it is fair to assume that a still larger part of the population of developed countries have become less intimidated by the aspects of adding hard- and software to their computers than say ten years ago.

The flexibility and current growth of the internet facilitates easier introduction of new communication forms and systems. Compared with the worlds of television, radio and telephony, new internet services *can* be introduced with less preparation and planning ahead. And they are: take for example IP-telephony, where at the same time over a

dozen different (and mutually uninteroperable) pieces of software are on the market. This is in sharp contrast to the way a new telephony service would formerly have been introduced. Again, the flexibility of the terminal equipment is an important factor, as the cost of trying a new communication form or system is limited to the cost of the necessary software - which is usually zero.

Product life cycles

The turbulence of the convergence landscape greatly influences the length of product life cycles (PLCs). Systems as fixed network telephony or television are characterised by standards, which are basically kept unaltered for decades. Today, both these sectors are undergoing a move from analogue to digital technologies - a fact that will undoubtedly add to the flexibility of the systems and induce a spawning of new communication forms and services. But still, the organisation of these systems are characterised by incumbent or state monopoly operators. This is changing with the ongoing liberalisation of the telecommunication markets, but the governing and standard setting organisations remain.

The imminent future holds promises of the flexibility of the computer/networking sector migrating into the telephony and television/radio sectors. Phenomena such as Bluetooth and Sun's Jini system aims at adding inherent flexibility and interoperability to the terminal devices used in these sectors. In line with the earlier argumentation, this will lead to an increase in innovation dynamics and a shortening of PLCs -and then, the same terms of rapid innovation will apply in these sectors.

Quickness

Communication networks are subject to so called positive feed back with regards to the adoption of technologies and services. This is due to the fact that new users tend to favour systems, which already have a large number of users. Therefore, an important precondition for success in battles among interoperability and compatibility standards is a quick take-off after market introduction of the product or service in question. In a competitive scenario as this, it is obvious that a long phase of reaching consensus ahead of the introduction of a product or service tends to give the competitors a head start. This of course, is no issue if there are no competing standards (as has largely been the case for the old SDOs and RSOs), but in today's - and especially tomorrow's - landscape of electronic communication, market players will be pressed for time.

The emphasis on speedy market introduction and rapid succession of improving standards is leading to a change in time of the bulk of the standardisation processes. Where earlier, time was ample, there was a tendency to define most of the standards in a given technology *before* introduction. Today, a trend towards standardisation during

the actual use of the standard can be observed - whereby the sponsors of that standard saves the time consuming consensus reaching process in favour of earlier market introduction. Given the flexibility of communication devices and infrastructure, this approach, furthermore, has the benefit of leaving room for responding to market demand and adjusting future versions of the product or service accordingly. One might say that the future will favour more dynamic standardisation processes instead of a static ones. Here, the term "dynamic" implies that the standard is adjusted over time to suit new applications and needs. A static standard, by contrast, is described before market introduction and remains virtually unchanged during the remaining product life cycle.

Consortia

The changes outlined above do not suit the way that traditional SDOs and RSOs have been operated. Instead, other generic forms of standardisation bodies have good chances of influencing the future development. These are the so-called *consortia*: groups of players - often manufacturers and service providers - who have a commercial interest in seeing their standards and, thereby, products and services succeed.

A number of important differences between consortia and SDOs are described by, e.g., Ken Krechmer in Communication Standards Review⁴³⁶. Especially in the following areas, relevant differences can be identified:

Funding source

While consortia are often funded by dues paying commercial organisations, SDOs and RSOs may receive significant government support. The consortia's project specific funding makes their work shortsighted and focused.

Standards promotion

Due to their focused funding, consortia have good means of promoting their standards. For the SDOs and SROs, a slow and cumbersome funding application process is necessary in order to obtain funds for promotion.

Brands

In comparison with the consortia, which are often formed for the purpose of defining one single standard, the names of well established SDOs and SROs are in themselves effective brands.

⁴³⁶ Krechmer, 2000.

The strategic considerations of consortia

One of the fundamental choices of a player on the market of electronic communication is his position with regards to interoperability and compatibility. An innovator can aim for obtaining a large basis of licensees supporting his standard or - if he thinks himself sufficiently strong - aim at keeping the standard to himself. This strength depends partly upon the appropriability regime⁴³⁷ of the innovator and partly upon the extent to which the standard can be substituted with a competing one.

In a scenario where an innovator, or standards sponsor, has a strong appropriability regime plus a product or service he thinks can prevail even without allies, this sponsor will be inclined to keep the standard to himself. The classic example of this scenario is the Betamax video recorder format developed by Sony. As opposed to its fiercest competitor, Matsushita/JVC, Sony chose a tight licensing policy. History proved Sony wrong. It is only seldom that a scenario will grant this strategy the victory. Even more so in the telecommunication sector, with its strong tradition for governmental intervention. Whereas governmental intervention with enforced license agreements is less likely in the case of a luxury good such as the video recorder, it is highly probable in the field of telecommunication - an area where considerations of "the common benefit" often come into play.

A follower, on the other hand, has little choice but to find a standard to follow. That in turn raises the question of which particular one among a number of competing standards to join.

The future: Converged standardisation

The previous chapter could almost be interpreted as a prophecy of the fall of the old SDOs and SROs. And obviously, one cannot exclude the possibility of consortia taking over some of the areas, which traditionally belong to the SDOs. Two future trajectories of development can be imagined. The first one describes the SDOs maintaining their work of developing standards; the second lets the SDOs assume a more regulatory role. This does not necessarily imply that the future will bring one of these two scenarios - but they represent two extremes of the spectrum in which the SDOs can be expected to operate.

Credibility

Firstly, the scenario needs not necessarily change as radically as expected by some standardisation theorists. Various consortia have admittedly had considerable success over SDOs in various areas. However, though failures are not unknown to SDOs,

⁴³⁷ The appropriability regime is defined by the innovator's means of internalizing the potential profit of the innovation - for example patents are considered strong appropriability regimes.

consortia might be even more prone to failure. Any market player can establish a consortium, propose a standard and introduce it on the market. Even sponsorship from well-established brand names is no guarantee of success of a consortium.

The future might then bring about scepticism of consortia standardisation. Here, the old SDOs could have a role as the trustworthy standardisation fora. If consortia standardisation in time proves to bring too many short-lived standards to the market, the expense and irritation of users and customers could make the opinion shift in favour of the well-established standardisation authorities with strong brands. Then, SDOs sticking to standard development in competition with the consortia is not at all unthinkable.

Another important issue is the maintenance of established standards. Here it is fair to assume that SDOs have resources and incentives to maintain and improve the already existing standards. The consortia, in contrast - if not entirely closed after standards development - tend to feel less obliged to continually supporting their standards.

Bridging gaps, patching holes

Another fact to bear in mind is the aims of the standardisation fora. While SDOs often to some extent rely upon governmental financing, the consortia have no obligation with regards to the common benefit. Introductions and promotions of consortium standards can very well be directly disadvantageous to the public. Left solely to the market forces - i.e. consortium standardisation - the telecommunication market will surely display numerous incompatibility and interoperability problems. These problems will then remain unsolved, as no commercial player will undertake them - to some players, absence of compatibility or interoperability might even be desirable.

The SDOs might also undertake those standardisation tasks, important to the common benefit - tasks which no commercial player or consortium sees the pecuniary incentive of undertaking. For example, in some standardisation battles, a final result can be long underway, and none of the competitors might yield. Here, the common benefit would often gain from a common (global) standard or a gateway/interface uniting the two standards.

In the case where a common standard is desirable, governmental support can provide the legal backing for the SDO to undertake the task of integrating the competing standards. Alternatively, if the lack of interoperability could be solved with gateway or adapter systems, the SDO could specify such standard - or have it developed by a commercial player.

The Shaping of Television

Course # 67495 History of Technology, Technical University of Denmark



Early vision of home-screen delights, by Robida⁴³⁸

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⁴³⁸ The Farnsworth Chronicles.

Introduction

On the internet today we see the potential of IP-telephony released. People worldwide can communicate with a wide array of information forms – audio, text, video and as the latest advance: shared whiteboards where graphical conceptions can be instantly mediated over vast distances.

The internet can certainly be seen as a catalyst of technological development, stimulating inventions and innovations in the communication area. But why hasn't these technologies been available to the public long ago? The possibility of transmitting text and audio has been available since the 19th century. With the development of television in the early and mid 20th century, one could imagine that video telephony would be available to common households in countries with a well developed communication infrastructure⁴³⁹. This, however, is not the case. Instead of offering enhanced one-to-one communication options, Television has turned into a broadcasting technology.

The purpose of this report.

This report attempts to explain, which technical preconditions and influences made television become a one-to-many, non-interactive medium.

The report identifies the technological origins of television as well as the intentions of the original developers with this medium. Through studies of selected sources, I will try to clarify why television became what is later described as a class I communication medium - whether it is due to inherent properties of the CRT (Cathode Ray Tube) technology or due to the inclinations of developers.

With the limited time available for this work, a completely thorough description and analysis of the shaping factors of television cannot be expected. The mission of this report is rather to draw the lines for future examinations into this field than to claim a complete roundup of all relevant shaping factors.

My point of departure.

This report is intended to contribute to my Ph.D.-dissertation: "The Convergence of Tele-technologies - Distributed Multimedia". In my work I aim to describe the inherent characteristics of the converging sectors - IT, Tele and Broadcast. My original field of expertise being the IT sector, I need to achieve further knowledge on the historical origins of the Tele and broadcast sectors. A colleague on CTI has written several articles on the history of telephony, and with my knowledge of the

⁴³⁹ Here, communication infrastructure is defined as the antennas or wires necessary for transmitting information – i.e. the physical infrastructure.

backgrounds of IT and Internet, a basis for the description of the historical development of broadcast is a central component in the PhD. project.

As my educational background is technical, this report will focus on the technical properties of television. Alternatively I could have chosen other angles of attack - describing organisations, key persons etc. However with my Ph.D. project being of a mainly technical character, and the extent of this report being limited, I will only sporadically describe the people and organisations pushing the development of television.

My view on technological development is to a certain extent inspired by actor-oriented theories (as e.g. the Social Construction theory). According to this view on technology, there is a certain period of time following the introduction of a new technology - a period in which the technology finds its future form defined by the interpretations of the actors (primarily the users of the technology). Thus one of my tasks in the report is to identify the period in which the shaping of television took place. This span of time is expected to display signs of the conflict between the different views on the proper application of television. I expect these two interpretations to be on the one hand a one-to-many information delivering medium and on the other hand a one-to-one communication device.

Definition of problem and focus.

As suggested earlier, the central question, posed by this report is why television became a "public service" medium instead of a person-to person communication technology, and whether a certain crucial period of shaping can be observed. This I expect to do by identifying influential factors in the development process and by suggesting a "lock in"⁴⁴⁰ of the technology.

The report will focus on the technical properties of the components of television as a technology - as a broadcast system as well as a "telephone-like" device. I will attempt to identify the critical period of development - the time span in which the purpose of the technology was defined.

Supplementary to the technical descriptions, I will touch upon the roles of key persons as shaping influences. This is due to the assumption that technology is more than merely tangible hardware. My main focus will however remain on the technical development, but when circumstances demand it, people are mentioned.

⁴⁴⁰ "Lock in" meaning the event when a common interpretation of the use of the technology is established.

The report does not put a geographical view on the development process. It is usually specified in which countries inventions and developments take place, but no comparison between different countries or regions will be given.

Communication theory

Before describing a certain communication technology, one must define what is meant by the term "communication". Especially with the rise of multimedia as a manifestation of the convergence process, several suggestions for a suitable communication taxonomy have been applied for different purposes.

Though I cannot claim any particular expertise in this field, I have selected the below described taxonomy of communication media by Bretz⁴⁴¹ for initial identification of television in its current form.

Class I -- Audio-motion-visual media. This covers audio, mixed with motion-visual media. Examples include television, film, cartoons etc.

Class II -- Audio-still-visual media. This covers still visual media accompanied by audio. Examples include documents with voice annotations, and pictures supported by voice-overs.

Class III -- Audio-semi-motion media. Semi-motion media are described as being capable of pointing and build-up but do not include the capacity to transmit full or realistic motion. It is felt that any medium that updates at a rate below 5 updates per second may be classed as semi-motion. Examples include animated diagrams, slow scan television etc.

Class IV -- Motion-visual media. This class includes all the capabilities of Class I, but without the supporting audio channel. Examples include silent film, and animated diagrams.

Class V -- Still-visual medium. This class of media represents visual media without motion. There is no explicit concept of motion, and the medium is not temporally dynamic. Examples include photographs and printed pages.

Class VI -- Audio media. This is the sound-only medium.

Class VII -- Print media. This class covers only alphanumeric and symbolic characters.

⁴⁴¹ Pearcey.

Among these seven classes, television today can be described as a class one communication form (it is even used as an example of class one communication above).

It is not quite obvious which use the classification above will have in the paragraphs later in this report. Obviously, many of the technologies influencing television (silent movie, telex, etc) can also be classified in the taxonomy. The foremost purpose of introducing this theoretical tool is to illustrate, that the development of television might fruitfully be put in the context of communication theory.

The television as a technological system

Television should be seen as a complex technological system rather than merely an apparatus on which to view moving pictures. Television as we know it today consists among other components of organisations, users, producers AND the whole technical system from input to output – the latter of course being the focus of this report.

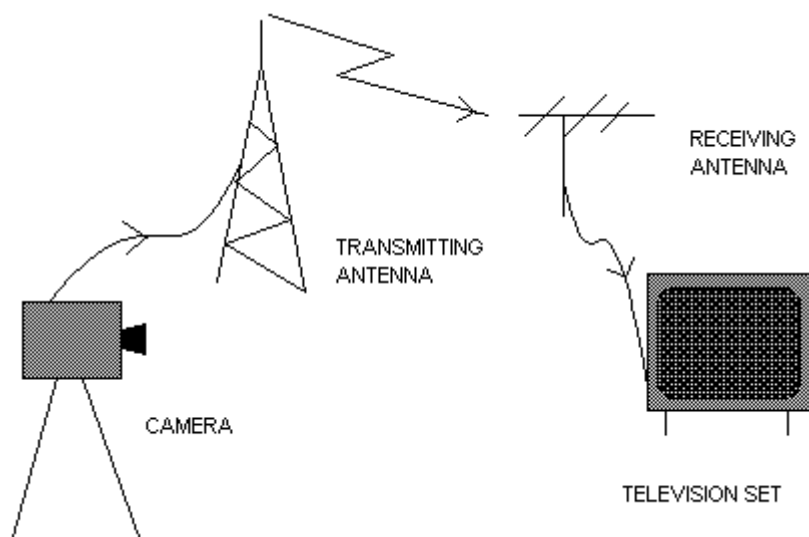


Figure 61: The basic technical system of television.

Based on the above identified main components of television technology, each component will be subject to a description of it's technical development and an analysis of it's influence on the development of television into a mass medium rather than a one-to-one communication tool.

The above figure displays the elements of television as a broadcast technology consisting of a camera (the input device capturing images), a transmitting antenna, a receiving antenna and a television monitor (the output device). Television as a one-to-

one, two-way communication technology can easily be imagined by adding a reverse system to the already existing systems - meaning a camera AND a monitor with necessary transmission equipment at BOTH ends.

The reasons for the outcome of the development process - broadcast instead of interpersonal - will be sought in the separate components of the system:

- Input device
- Transmission systems
- Output device

Early conceptions of Television

Originally, television might not have been developed for the purpose of broadcasting. In the late 19th century, the technological forerunners of television were envisaged as interpersonal communication technologies:

By the end of 1887, the combination of Bell's telephone and Edison's invention of the phonograph (1877) combined with progress being made in photography led the magazine Punch to print a cartoon of a new Edison invention the "telephonoscope". Here was depicted a two-way visual system on a wide screen depicting parents in London speaking with their daughter in Ceylon by means of an "electric camera obscura" and telephone. Edison did not apply for a patent on a motion picture system until 1889. It is ironic that Punch should have Edison invent an "electric camera" before he invented the motion picture camera. But there were many schemes for visual communication gadgets at the time.⁴⁴²

As discussed later, the property of the camera (whether it transmitted images immediately or stored them on a medium for later transmission), is of great importance to the shaping of television. Already before the turn of the century, ideas of the necessary properties of the camera were presented.

... one could go back at least to the invention of the telephone to see well-developed conceptions of the medium which would later bear the name "television." I have argued elsewhere that a conception of the medium took hold in the last quarter of the 19th century which would in crucial ways determine the distinctions among moving image media. Inspired by the telephone, early notions of the televisual assumed that moving pictures would be seen simultaneously with their production, that is, that the medium would

⁴⁴² Smith, 1998, p.10.

*serve as something like an electronic camera obscura or telescope, bringing spatially distant scenes into direct visual proximity with the viewer.*⁴⁴³

This indicates that the idea of video telephony is not at all new. As later suggested, the crucial period of definition of television as a communication technology probably was the time between 1925 and 1935. However, also after this period of definition, considerations regarding the possibilities of television were topical. An example of the speculations around the future of television from the mid-1930's Germany can be seen in William Uricchio's account:

Acutely aware of both the financial and ideological implications of the medium's identity, various factions in the German electrical industry, the government, and the National Socialist party fought over the vision that would shape television. Was television the technological completion of radio, with which it shared a common technological heritage and industrial base? If so, should it be conceived as a domestic medium with radio-like programming? Or was it more like film, with which it shared imagistic conventions? If so, then should collective public viewing and cinema-like programming be expected to dominate? Or was it more like the telephone, offering individual, point-to-point communication possibilities? If so, then should television simply complement the existing telephone by offering visual service? In fact, all of these models and more were actively put to use in Germany and elsewhere between 1935 and 1944. But the arguments deployed in the support of these views offer vital insights into how the medium was being conceptualized, and at the same time, how it jostled for position in an already well-established media landscape.⁴⁴⁴

Here, it has been shown, that television by no means was "born" as a broadcast technology. The influence of users' and producers' perceptions of the technology can of course have had a central influence in turning television into a broadcast technology, but it certainly was not the only vision of the future.

Relevant historical developments:

It is impossible to point out a certain invention and define it as television. Some of the technologies and concepts needed have been known to mankind for a long time. An example of visual communication over longer distances dating back thousands of years is the transmission of light reflected with mirrors via relays on hilltops.

The development of the technologies more closely related to television as we know it today began in the 19th century. The timeline below provides an overview of the steps in development until present day:

⁴⁴³ Uricchio.

⁴⁴⁴ IBID

*Brief History of Film, Video, and Television Technology*⁴⁴⁵

1872 – 1877: Eadweard Muybridge shoots a series of motion photographs, which can be viewed by mounting them to a stroboscopic disc.

1884: George Eastman invents flexible photographic film.

1887: Thomas Edison patents the motion picture camera, though it cannot produce images.

1888: Thomas Edison and William Kennedy Laurie Dickson attempt to record motion picture photos onto a wax cylinder.

1891 – 1895: Dickson shoots numerous 15 second motion pictures using Edison's kinetograph, his motion picture camera.

1895: First public demonstration of motion pictures displayed in France.

1897: Development of the cathode ray tube by Ferdinand Braun.

1907: Use of cathode ray tube to produce television images.

1923: Patent for the iconoscope, the forerunner of the modern television picture tube.

1927: Talking films begin with Al Jolson in "The Jazz Singer".

Early 1930s: RCA conducts black and white broadcasting experiments.

1936: First television broadcast made available in London.

1938: Initial proposal for color television broadcast made by George Valensi.

1949: System developed to transmit chrominance and luminance signals in a single channel.

1950s: Hollywood looks to recover profits lost to television by introducing such formats as 3D and Cinemascope.

1954: FCC authorizes the NTSC standard for color television broadcast in the United States.

⁴⁴⁵ Author unknown: *Brief History of Film, Video, and Television Technology*.

1975: Sony markets the first Betamax VCR for home viewing and recording of video.

1976: JVC introduces the VHS format to the VCR arena.

1976: Dolby Laboratories introduces Dolby Stereo for movies.

1978: Philips markets the first video laser disc player.

1984: The first Hi-Fi VCR is introduced.

1985: The broadcast of stereo television.

1994: Standard agreed upon for high definition television transmission in the United States.

This timeline is useful for creating a perspective of the development. However, it is necessary to "zoom in" on the period where the development of the technical systems took place. Here, the technology probably wasn't locked in by institutions - such as well established broadcast companies - but was still open to interpretations.

I have searched for examples of early regular application of television as a): visual interpersonal communication and b): Broadcasting. No evidence of the first mentioned application was found, but broadcasting appears to have begun in the thirties. Narrowing the focus to the early broadcasts as identified by Barry Mishkind⁴⁴⁶, the milestones on the technical front were concentrated in the 1920's:

The first experimental TV broadcasts:

1924: John Logie Baird broadcasts a picture of the Maltese Cross. This was a mechanical system, with a resolution of 30 lines.

November 18, 1929: Dr. Vladymir Kosma Zworykin demonstrates his cathode-ray tube receiver at an IRE meeting.

July 30, 1930 NBC opens W2XBS.

July 21, 1931 CBS opens W2XAB.

In June 1936, the Don Lee Broadcasting System starts the first public demonstration of CRT television with daily broadcasts of 300 line pictures using Harry Lubcke's system.

⁴⁴⁶ Mishkind.

Regarding the organisation of television broadcast - seen as the ability to transmit programmes on a regular basis, Mishkind has identified the following milestones:

The first regular TV transmissions:

March 1935 - the German government began its national service. This was the first non-experimental public television service.

November 11, 1936 - The first scheduled television broadcasts in the UK began. (The Baird and the EMI systems were rotated on a daily basis until February 4, 1937, when the EMI system was adopted, and Baird's was dropped.)

1939: The first regularly scheduled television broadcasts in the USA began.

1941: The first sponsored television broadcast appeared in the US.

July 1, 1941 - The first commercial TV licenses were issued to WCBW (later WCBS-TV) and WNBT (later WNBC-TV), New York City. (On September 1, 1941, KYW-TV, Philadelphia became the third licensed station for commercial operation.)

January 9, 1947 - KTLA (one of the first in the western US) received an STA for commercial operation on an experimental tv station (previously

W6XYZ). An "official" license was issued 2/9/53. KTLA Opening night featured a special live 30-minute show from the Paramount TV stage, featuring Bob Hope, Jerry Collona, Dorothy Lamour, and William Bendix.

It is nearby to assume, that the technology of television was open to interpretations⁴⁴⁷ until regular broadcasts began. This means, that there probably has been a critical span of ten years between 1925 and 1935, where the shaping of television took place. In this period, the influences that pushed television in the direction of broadcast instead of point-to-point communication might be identified.

The input device (the camera)

The technology for capturing moving pictures is of particular interest to this report. The price and availability of cameras must have had significant bearing on the chances of television as an interpersonal communication technology. To transmit your own image, a camera is necessary, and if cameras are expensive or scarce, television logically is more likely to become a broadcast technology with expensive cameras located with central broadcasters.

⁴⁴⁷ Interpretations meaning that the technology could be shaped according to the perception of the actors (i.e. users, inventors, etc.)

Another interesting property of cameras is their ability to transmit images immediately. Cameras storing images on a medium with delayed distribution in view are obviously not suitable for real-time communication as e.g. a telephone. For broadcast purposes this is no problem - it might even be an advantage, as editing and storage is possible with a recording medium. But for interpersonal communication, such a system is unsuited. The delay between transmissions would be too great for the communication to resemble face-to-face conversation.

The first practical camera for scanning moving pictures was invented by Paul Nipkow, who took out a German patent on the device in 1884. The apparatus' central component was a disc with 24 holes in the outer rim with a selenium cell as the unit registering the variations in light. The receiver unit was a quite similar device with the selenium cell emitting light through the holes in the rotating disc⁴⁴⁸.

Nipkow's invention was followed by a series of improvements and alternatives in the following years (see for example Smith⁴⁴⁹). But until and during the crucial period of 1925-35, the Nipkow disc remained a key component in many television experiments. Apparently - as literature suggests (see e.g. Smith) - Nipkow's invention had a life span that reached well into the critical period.

Three central persons appear to have had significant influence on the development of input devices for television. The Scotsman John Logie Baird began experiments on television including a Nipkow disc for capturing motion pictures in 1923, but with an array of lights for displaying the images at the receiver end⁴⁵⁰.

Also in 1923, Vladimir K. Zworykin made a significantly different system. Here, the camera was all-electric with an aluminium foil plate covered with potassium hydride for scanning images⁴⁵¹. There is no evidence on the complexity or price of the different cameras to be found in the literature, but it is likely to assume, that an all-electric device would be cheaper in mass production due to the comparative complexity of mechanical systems. This is an interesting consideration: If television should have a chance of becoming an interpersonal communication device, cameras must not be too expensive. Unfortunately, I have found no indication of the cost of cameras, so the consideration is unsubstantiated.

A couple of years later, Philo T. Farnsworth applied for a patent on a completely different all electric television system which to a large extent resembles the analogue video cameras of today. The scanning unit was a photoelectric plate, which converted

⁴⁴⁸ Smith, 1998, p.10.

⁴⁴⁹ IBID, pp. 10-13.

⁴⁵⁰ IBID, p.13.

⁴⁵¹ IBID, 1998, p.13.

the variations in light into electricity⁴⁵². This camera might have been an even better suggestion for a common household device, due to its expected greater simplicity and derived robustness and low price

All the above mentioned input devices transmitted the signal directly to the receiver. As mentioned before, this is a necessary precondition for a well functioning interpersonal real-time communication system. The influences on the development of television into a broadcast technology should thus be found elsewhere. Regarding the prices of cameras - they might have been too expensive - no evidence has been found.

The transmission systems

The relevance of transmission systems in relation to the shaping of television is due to the bandwidth consuming nature of moving pictures. In analogue as well as digital systems, video *ceteris paribus* takes up several times the space of audio.

In the early experiments with television, transmission took place by air as well as by wire. Especially the first world war from 1914-18 gave rise to significant advances within the field of communication by wire as well as by radio⁴⁵³. This should indicate that the infrastructure needed for television in either of its forms was in place. However, it is obvious that a large number of persons having point-to-point communication takes up much more capacity than a broadcast over a limited frequency band.

In this respect, it would have been interesting to know the regulation of the communication infrastructure. I have tried to find evidence of transmission permission policy and frequency allotments in the early 20th century, but without success.

Concerning airborne television, the only indication of scarcity I've found is the following quote:

Between the 1950's and 1990's, television was organised as a regulated and essentially national medium dependent on the scarce resource of electromagnetic frequencies.⁴⁵⁴

It nevertheless suggests that the restrictions of use of frequencies has been an influence pushing television in the direction of broadcast. Considering that the signal compression methods have improved over the years, one can easily imagine, that a limited number of "video telephones" using radio transmission would have completely consumed the frequency spectrum available.

⁴⁵² Smith, p.15.

⁴⁵³ IBID, p.10.

⁴⁵⁴ IBID, p.1.

A possible influence from the regulatory side in USA comes from the Federal Communications Act of 1934.

*It specifies the Federal Communications Commission (FCC) as the regulatory agency responsible for seeing that broadcast outlets conform to the statute's requirements, which include the famous stipulation that stations serve the "public interest, convenience and necessity". What the FCC does, coupled with the actions of Congress, determines the number of television stations, the relative strengths of commercial and public broadcasting, and the way that both commercial and public stations behave.*⁴⁵⁵

Here is no indication of regulation of the allowed number of interpersonal communication devices, neither is their transmitted content specified. It is a nearby conclusion that it has not at all been a concern in the regulation processes - meaning that interpersonal television was considered unimportant.

If assuming that dedicated or telephone wires were used for transmission, bandwidth consumption is still an issue, as a "video call" presumably would have taken up many times the transmission capacity of a traditional phone call. If regulation wasn't an issue on copper wires, communication still might have been prohibitively expensive.

Regarding the possible use of a telephone infrastructure for interpersonal visual communication, there's ample evidence that this was an option. For example a demonstration in 1930 illustrated, that telephone lines could be used:

*The 2100-lamp screen which had been demonstrated in 1930 was replaced by a "flying spot" method, with the picture being traced out in strips by a powerful beam of light deflected on a rotating mirror drum. This technique was successfully used in the live showing of the 1932 Derby at the Metropole Cinema, Victoria. The overall picture size was 9 ft wide by 7 ft high [2.7 x 2.1m] and it was formed by joining three pictures 3 x 7 ft [0.9 x 2.1m] sent over three separate telephone lines.*⁴⁵⁶

The both-ways communication which is an inherent characteristic of the telephone system makes it obvious, that a double system with input and output devices at both ends was a possibility. However, as mentioned, the signal was sent over three telephone lines, meaning that six lines would be necessary for interpersonal real-time communication. With this great capacity consumption, it would have been very expensive in comparison with a traditional phone call.

John Logie Baird experimented with television via wires as well as radio waves.

⁴⁵⁵ Comstock, 1991, p.3,

⁴⁵⁶ Baird.

*Using post office telephone lines, Baird sent a "cable" television transmission 438 miles from London to Glasgow in 1927. The following year he transmitted images to the cellar of an amateur radio operator in Hartsdale, New York. It was the first transatlantic demonstration of television.*⁴⁵⁷

Again, we have an example of the feasibility of telephone lines as television infrastructure. Furthermore, it is illustrated, that a return path was available, as both amateur radio and telephone are two-ways communication.

An introduction of the television as an add-on to already existing radio receivers added to the establishment of the television as a one-to-many (broadcast) medium. Here, an already existing installed base of radio receivers was used for tuning the television signal. But these radios had no built-in transmitters, so the households' only option was receiving, not delivering information:

*The only public transmissions of television in 1932 were those of the BBC which were of 30-line definition, using the regular medium wave broadcast frequencies also known as the AM band. This had the advantage that it could be received by simply connecting a television apparatus (the Televisor) to a regular AM radio, and the signals could be received all over the UK and in parts of Europe.*⁴⁵⁸

The description of transmission systems suggests, that the technical properties of these systems in no way hindered the development of interpersonal television. However, it is likely that the price of having several phone lines available for video communication would have been too high for it to become a household application. Regarding the possibility of communication via radio waves, two interrelated factors might have been influential: Pure saturation of the frequency spectrum and regulation prohibiting interpersonal video communication. Unfortunately none of these two influences could be verified.

The output device

The relevance of the output device is less significant than for the other components. This is due to the fact that in whatever form of television technology - broadcast or interpersonal - the output device is a necessary component. Every broadcaster will need a monitor to view his own product before and during transmission. And obviously, every receiving party will need a monitor.

Therefore, the development of the cathode ray tube is not expected to reveal any significant factors influencing the development. For example price of a household TV

⁴⁵⁷ Uricchio.

⁴⁵⁸ Baird.

has a great influence on the adoption of the technology, but this would be the case for television as a broadcast as well as an interpersonal technology.

Nevertheless, a short description of the milestones in output device development is relevant⁴⁵⁹:

1900: Constantin Perskyi describes the idea of television based on the magnetic properties of selenium on the 1900 Paris exhibition.

1909: Max Dieckmann demonstrates operational cathode ray tube.

Ernst Ruhmer invents a display in the form of a matrix of 25 lamps.

Georges Rignoux demonstrates bisulphate carbon tube.

It should be noted, that the television systems of Baird, Zworkyn and Swinton each relied on a specialised output device⁴⁶⁰. This implies, that the whole system of input and output device would have been sold, purchased and used as an entity. One could imagine that a cathode ray tube was a "universal" output device functioning with whatever sort of input it had, but this was not the case.

The audio side

Although the audio side of television in either form is a central part of communication, it is not subject to much focus. The influence of audio on the development of television probably has been limited as it could be delivered on separate or same track as video, and delivered separately it was already a mature technology in the form of telephony.

Conclusion

Based on the analysis, no concluding factors pushing television in the direction of a broadcast technology can be identified. But a number of candidate factors can be excluded, and others can be further supported.

A possible hindrance to the development of television into an interpersonal communication technology could be the relatively high costs of input devices (especially in the light of people having a tendency to enjoy rather than produce information). There is no evidence suggesting this, but obviously the complexity must have made them rather expensive.

⁴⁵⁹ Smith, 1998, pp.11-12.

⁴⁶⁰ Smith, 1998, p.13ff.

Regarding the infrastructure, only circumstantial evidence has been found. Using phone lines can easily have been prohibitively expensive for this form of transport of signal to be realistic. The obvious alternative - radio waves - is a scarce resource, and with the development of radio technology during the first world war, it is likely to assume, that regulation has imposed severe limitations on interpersonal television.

Another necessary property of the infrastructure - the existence of a signal return path - was not a central obstacle to the development of television as an interpersonal communication technology, as both communication infrastructures subject to experiment - radio waves and wire - had the possibility of a return path.

An explanation of the development was also sought in the input devices' lack of capabilities of direct transmission without storage medium. But evidence shows that the early cameras sent the motion pictures directly to the receiver without storage. They could therefore have been used for interpersonal real-time communication.

The lock-in of the technology is defined according to the establishment of regular broadcasts. Thus, the crucial period where the important definition and shaping of the technology took place is estimated to be the period between 1925 and -35.

Discussion

The report comments and elaborates upon the assumptions concerning the development of television. A number of possible explanations have been researched, some have found further support and some have been rejected.

For further research into the field of early television development, there is a number of issues into which further investigation is needed:

In order to evaluate the effects of regulation on airborne interpersonal television, further information on bandwidth consumption, regulatory policies and frequency allotment must be obtained.

Also the alternative to airborne signals - namely transmission via copper wires needs further investigation. Information on how much bandwidth a signal would consume, how much bandwidth was available and to which price, is needed.

Further information on the prices robustness and complexity the different forms of input devices is also needed in order to estimate whether they had a chance of becoming household systems.

Due to the technical nature of this report, organisational issues have been subject to little attention. But since the development of television without doubt was a costly process, investigation into whether the early inventors were sponsored by radio

broadcast companies or telephone companies should be made. This is very likely to have had a great influence on the direction of their research and as a derived effect, the later application of television.

With the time available, these topics could not be further examined in this report. However, in relation to my Ph.D. dissertation, there is ample time to further investigations. With this in mind, the report provides an excellent basic for further research.

Method

17. This section describes the methodological considerations of this Ph.D.-project in further detail than is done in the “

Research Design” chapter, and defines the project in methodological terms.

The chosen method primarily depends on the purpose of the research taking place. Many different purposes of conducting research can be put forward, but three main categories can be defined:

The purposes of research are basically three-fold⁴⁶¹:

1) Exploration: to investigate something new of which little is known, guided by a general interest, or to prepare a further study, or to develop methods. The disadvantage of most exploratory studies is their lack of representativeness and the fact that their findings are very rudimentary.

2) Description: events or actions are observed and reported (what is going on?). Of course, the quality of the observations is crucial, as well as the issue of generalizability.

3) Explanation: this is research into causation (why is something going on?). This is extremely valuable research of course, but note that most research involves some of all three types.

An exploratory investigation

As mentioned before, the concept of convergence in infocom is very novel. Therefore, there is no established theoretical paradigm by which to form a priori expectations concerning the relations and patterns of various forms of infocom in transition.

The relations and explanations are sought using an exploratory approach. This implies that rather than forming hypotheses and verifying them in traditional positivist manner, the project investigates a number of infocom phenomena, aiming at identifying and describing systematic patterns and relations which serve to explain the present situation, as well as the scenarios preceding this situation and the possible scenarios that are to come.

Though the study sets out with an exploratory approach, it contains significant descriptive and explanatory elements, thus going beyond merely identifying the ongoing development.

⁴⁶¹ Deflem, 1998.

Inductive Method

The method of gaining insight is inductive rather than deductive, taking off from empirical observations in search for understanding of the findings. Again, this is due to the newness of the topic. The turbulent world of infocom convergence assuming new shapes by the turn of the millennium is in need of new views and explanations of the processes taking place.

If a positivist approach should be applied to a phenomenon such as convergence, it would be more suited for a non-contemporary phenomenon. In such a situation, it would be possible to make “token” predictions based on the hypotheses (which in turn are based on the theory) and actually compare these predictions with the real-life situation – thus supporting or falsifying the hypotheses.

This study does not attempt to categorize the observable processes and phenomena in traditional terms. It prepares to encounter processes, phenomena and relations that can not easily be explained within the boundries of a rigidly defined deductive research design. Thus, an open ended approach is needed.

A Qualitative approach

The purpose of this work is to clarify the properties of systems and phenomena – not to describe precisely how widespread a certain form of infocom might be or to find out the exact number of users of a different brand of computer.

This means, that the approach is qualitative rather than quantitative⁴⁶². Thus, the study will use observation as the main source of data, and focus at few cases and many variables. Therefore, the questions posed are in the form of “how” and “why”, rather than “how many” or “how much”.

Looking at the posed questions, one can select a research strategy best fitting nature of the posed questions and the topic of investigation. A very useful framework of strategy choice is provided by Robert K. Yin:

⁴⁶² This, however, does not mean that the study is “Qualitative Research” – see Yin, 1994, p.14.

| Strategy | Form of research question | Requires control over behavioural events? | Focuses on contemporary events? |
|-------------------|--------------------------------------|---|---------------------------------|
| Experiment | How, why | Yes | Yes |
| Survey | Who, what, where, how many, how much | No | Yes |
| Archival analysis | Who, what, where, how many, how much | No | Yes/no |
| History | How, why | No | No |
| Case Study | How, why | No | Yes |

Table 18: Relevant Situations for Different Research Strategies. Source: COSMOS corporation⁴⁶³

The research questions posed in this project are as previously mentioned of the “how and why” form.

The control of behavioural events is somewhat harder to relate to this project. The idea behind this part of the table probably has root in the fact, that the listed research strategies are imagined used for examining human behaviour. One cannot easily speak of the behaviour of hard- and software, but behavioural patterns certainly exist when looking at buyer and user behaviour as well as the behaviour of those companies and organisations involved in standardisation processes. The central point here, is that behaviour is an issue, but control of behavioural events is not at all required to conduct a study of the convergence of infocom.

The last column has to do with the issue of time. At the time of writing, convergence is taking place. Even though a historical perspective is applied to e.g. the television area to supplement the findings, the study must be said clearly to focus on contemporary events.

Due to these circumstances, the choice of case studies as research strategy is supported.

A Case Study

As pointed out above, the chosen research strategy for this Ph.D. project is case study. The use of case studies as research method is usually associated with e.g. anthropological studies within the domain of social sciences, and seldom with studies

⁴⁶³ Yin, 1994, p.6.

of such technical a nature as this project. However, the nature of the convergence process and its many uncertainties justify the use of this approach.

One of the most acknowledged advocates of case study research is Robert K. Yin. In “Case Study Research”. Here, Yin states, that:

*“...we can also identify some situations in which a specific strategy has a distinct advantage. For the case study, this is when a “how” or “why” question is being asked about a contemporary set of events over which the investigator has little or no control”*⁴⁶⁴

An attempt to answer one’s research questions with the aid of case studies implies choosing one or more cases, which are investigated with the purpose of identifying possible explanations to one’s research questions.

As this form of study only is able cover a fraction of the whole bulk of possible explanations, it is an inherently inductive form of research. As such, the results gained by case studies will not lead to certain conclusions or theories. But then, no research method is able to do so. A deductive approach with a statistic empirical body would not be able to provide completely certain results either. And, the topic of investigation being a novel area lacking an established theoretical paradigm, the study should rather be a search for new explanations than a positivist test of established theories. Therefore, case study has been chosen as the method of gaining empirical information about the topic of the project.

*“A case study is an empirical enquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between the phenomenon and context are not clearly evident”*⁴⁶⁵.

Here, it is necessary to clarify what could result in a confusion of terms. Yin’s use of the term *phenomenon* is equivalent to the *process of convergence* in this report. This report uses the term *phenomenon* to describe those forms of infocom manifested in hard- and software plus methods (sometimes referred to as *brainware*). Here the phenomena are the cases subject to investigation.

Definition 32: A phenomenon (a stipulative definition).

Further defining the concept of case study, Yin explains:

The case study inquiry copes with the technically distinctive situation in which there will be many more variables of interest than data points;

⁴⁶⁴ Yin, 1994, p.9.

⁴⁶⁵ IBID, p.13.

*and as one result relies on multiple sources of evidence, with data needing to converge in a triangulating fashion; and as another result benefits from the prior development of theoretical propositions to guide data collection and analysis*⁴⁶⁶.

Again, it is necessary to explain a term in this quote. The notion of variables and data points can seem somewhat unclear. Applied to the topic of this report, *data points* relate to the case candidates – i.e. the phenomena that can be subject to investigation. The *variables* are the properties of those data points which can be of interest when searching for explanations. An example of a variable could be the flexibility of a signal interface. When bearing the definitions of data points and variables in mind, the situation under investigation – i.e. the convergence process – fulfils this criterion, as the data points (i.e. possible units of investigation) are very few compared to e.g. a whole country's population of several millions. The variables, which can be imagined to influence the convergence process, are many compared to e.g. the simple matching of age and personal income among individual humans.

The choice of case studies in situations with few observation units and many variables are supported by a number of sources⁴⁶⁷, and is accepted as a suitable method for this project.

Multiple Cases

Within the discipline of case studies, there are two distinct forms: Single and Multiple Case studies. Multiple case studies – which is the method chosen for this project – analyses not only one, but a set of cases to illuminate a question or problem.

A reason for looking at more than one case is to achieve a more robust result. This means that if the findings in a number of cases support one another, it leads to a stronger argumentation than if only one case had been subject to investigation.

Apart from the distinction between single- and multiple case studies, another distinction is relevant here. This has to do with whether the study is holistic or embedded. Thus, the choice of study can be illustrated in the below matrix.

⁴⁶⁶ IBID, p.13.

⁴⁶⁷ See e.g. Andersen, 1999, p.163

| | Single Case Designs | Multiple-case designs |
|--|---------------------|-----------------------|
| Holistic (single unit of analysis) | Type 1 | Type 3 |
| Embedded (multiple units of analysis). | Type 2 | Type 4 |

Table 19: Basic Types of Designs for Case Studies. Source: COSMOS corporation⁴⁶⁸

Within this matrix, the study carried out in this project belongs to type 3, as it is a holistic multiple-case study

Yin is not very specific on the distinction between holistic and embedded case studies. An attempt to clarify these terms is done by Andersen⁴⁶⁹. Here, Yin is quoted for stating that the purpose of the holistic approach is to provide an understanding of the case/system/phenomenon as a whole. As an opposite to the holistic approach, Andersen mentions the *analytical* approach, which is inconsistent with Yin's term "*embedded*". Still, using Andersen's elaboration of the term "holistic", the embedded approach - which is mentioned as the opposite of holistic - must refer to a division of the unit of analysis into subunits.

This lack of clarity poses a dilemma for this thesis. One can say, that the unit of analysis is the whole field of convergence, but on the other hand, the thesis applies an understanding of *three converging areas*, among which two are subject to analysis. Thus, one could also speak of two units of analysis: The television and the computer/networking area. When viewing the two areas as a whole convergence area, the study carried out here is of type 3. However, if this latter view is applied, the study is of case 2.

Components of the research design

Yin suggests five basic components of a research design⁴⁷⁰.

The Study's Questions

The "study's questions" as defined by Yin are equivalent to the "Research problem" of this project. The research problem poses the major and fundamental questions guiding this study. These are described in the "Research problem" chapter, and will not be further elaborated upon here.

⁴⁶⁸ Yin, 1994, p.39.

⁴⁶⁹ Andersen, 1999, p.167

⁴⁷⁰ Yin, 1994, p.20 ff.

The Propositions

These are what is referred to as “research questions” in this dissertation. They are derived from the study’s questions (or the “research problem”) and point out the properties and relations that are sought identified via the case studies.

Unit of analysis

Though this particular concept is difficult to define, this study’s unit of analysis is regarded to be the sum of appliances and infrastructures of the areas involved in the infocom convergence. Within this unit of analysis, a specific focus area has been selected as described in the “Focus and Demarcations” section. It is a question of scope and definition whether to speak of one unit of analysis or a number of units of analysis. As the study also involves standardisation traditions, interconnection interfaces etc., these might as well be defined as units of analysis.

Though the cases chosen are determined by the units of analysis, the two terms should not be confused. While the unit of analysis is defined as a particular layer or cross-section of the areas of television and computer/networking, the cases are found as elements within the bulk that constitutes the unit of analysis. These are the phenomena⁴⁷¹ – i.e. the actually observable pieces of hard- and software relating to a certain form of communication or information consumption. The chosen method - case-study - is often perceived as a study focusing on human groups or individuals. This is not the case in this work, where the main focus is on technical rather than human issues.

In the choice of units of observation, there are two important pitfalls to be aware of:

- *Ecological fallacy, i.e. making assertions about individuals on the basis of findings about groups or aggregations.*
- *Reductionism, i.e. illegitimate inferences from a too limited, narrow (individual-level) conception of the variables that are considered to have caused something broader (societal).*⁴⁷²

Though the text referred to exemplifies these issues with studies of individual humans, the importance of these issues certainly also apply when the unit is a piece of hard- or software. Avoiding the pitfalls is more a question of common-sense responsibility than something that can be implemented in the method. However, being aware of these pitfalls and reviewing one’s findings having them in mind gives considerable assurance against drawing false conclusions.

⁴⁷¹ The focus on phenomena should *not* be seen as an indication that the study is phenomenologic in nature.

⁴⁷² Deflem, 1998.

Logic linking of the data to the propositions

According to Yin, this component of the research design is one of the less well-described ones. He suggests “pattern-matching” as a possible approach. The tools used for this approach seem rather unsystematic and based on common-sense interpretations of the patterns identified.

This work views the identified data in the light of the selected theory and attempts to answer the proposed questions – and in turn the basic questions of the research problem. This is done by argumentation of the importance of the identified relations and properties and by accounting for other factors outside of the focus of this work which might supplement the findings. Hereby, the inherent danger of reductionism brought about by defining the focus (and thus eliminating a number of influential factors) is reduced.

Criteria for interpretation

As is the case with the exercise of linking data to propositions, there is no established method of setting criteria for interpretation. As Yin puts it: “*Currently, there is no precise way of setting the criteria for interpreting these types of findings*”⁴⁷³. He suggests the use of rival propositions, the comparison of which might result in contrasting patterns.

This thesis uses neither rival hypothesis nor rival propositions. Instead, it relies on the coherence of the selected theory, the chosen research questions and the defined scope of this study. Hereby, a sound framework for interpreting the findings is established.

Sources of Evidence

A crucial element in any scientific study – whatever method chosen – is the source of evidence. The choice of sources highly depends on what form of investigation, one wants to conduct. A quantitative study typically requires large amount of numerical data, whereas a qualitative study rather requires information that clarifies the nature and more subtle properties of the topic of investigation.

Yin does a very useful taxonomy of sources of evidence. It lists six generic sources of evidence and points out strengths and weaknesses of each type of source.

⁴⁷³ Yin, 1994, p.26.

| Sources of evidence | Strengths | Weaknesses |
|-------------------------|---|--|
| Documentation | Stable – can be reviewed repeatedly Unobtrusive – not created as a result of the case study Exact – contains exact names, references, and details of an event Broad coverage – long span of time, many events, and many settings | Retrievability – can be low Biased selectivity, if collection is incomplete Reporting bias – reflects (unknown) bias of author Access – may be deliberately blocked |
| Archival Records | (Same as above for documentation) Precise and quantitative | (Same as above for documentation) Accessibility due to privacy reasons |
| Interviews | Targeted – focuses directly on case study topic Insightful – provides perceived causal interferences | Bias due to poorly constructed questions Response bias Inaccuracies due to poor recall Reflexivity – interviewee gives what interviewer wants to hear |
| Direct Observations | Reality – covers events in real time Contextual – covers context of event | Time-consuming Selectivity – unless broad coverage Reflexivity – event may proceed differently because it is being observed Cost-hours needed by human observers |
| Participant-Observation | (Same as above for direct observations) Insightful into interpersonal behavior and motives | (Same as above for direct observations) Bias due to investigator's manipulation of events |
| Physical Artifacts | Insightful into cultural features Insightful into technical operations | Selectivity Availability |

Table 20: Six sources of evidence: Strengths and Weaknesses⁴⁷⁴

This taxonomy is not exhaustive, but contains the vast majority of sources of evidence in use. Among the sources mentioned, the researcher should choose those best suited for her or his study.

⁴⁷⁴ Yin, 1994, p.80.

Multiple Sources of Evidence

In addition to listing the generic sources, Yin recommends the use of multiple sources of evidence: “*A major strength of case study data collection is the opportunity to use many different sources of evidence...*”⁴⁷⁵. For this Ph.D.-project, sources of evidence are selected with the circumstance in mind that the topic of investigation contains mainly technical aspects, but also aspects related to organisation, distribution, markets and usage scenarios. Hence, the bulk of evidence is sought within the categories of direct observation, and physical artefacts.

Compared to e.g. an anthropological study, the *direct observation* is conducted from a distance. The focus here is on the development of key soft- and hardware, content and services during the course of the Ph.D.-project⁴⁷⁶. The development of the convergence landscape before and during the project, are subject to investigation through actual observation as well as practical use of emerging and developing methods, practices, products and services.

Also the *physical artifacts* are subject to great interest as sources of evidence. Due to the focus being very much on appliances – and to some extent on infrastructures – the actual pieces of hardware are investigated. Hereby, insight into the potential and flexibility of individual components (hardware as well as software) as well as systems and converging areas can be gained.

The *documentation* is also of considerable interest. This can be documentation of hard- and software, offering thorough understanding of functionality of components. In addition, documentation of the less tangible elements as e.g. standardisation procedures is useful in understanding the organisational aspects of convergence. A different form of documentation is *roadmaps* in which companies and organisations predict their future development.

Participant-observation is a form of evidence gathering one might not associate with a study of a so technical nature as this. However, it has been explored to some extent – primarily in the form of participation in internet forums concerned with software, hardware and service development. This has resulted in a knowledge which has considerable value for the author’s overall understanding of the area of interest. However, the participation has not been sufficiently deep, and the involvement of this author has therefore been as an advanced user specifying needs and suggesting changes rather than contributing to actual development of products and services. Therefore, this category of evidence is of little significance by itself

⁴⁷⁵ IBID, p.91.

⁴⁷⁶ The project was started early 1998 and ends medio 2002.

To summarise, this study

- Is exploratory, but also explanatory and descriptive
- Uses an inductive method rather than a deductive one
- Uses a qualitative rather than a quantitative approach
- Is a multiple case study
- Uses multiple sources of evidence

Economics of Innovation

This section elaborates upon the theories of innovation, primarily presented by Dosi and Hughes. These theories are not directly applied upon the research problem of this dissertation, but play an important role in delivering a set of descriptive terms and aiding in the definition of the conceptual framework.

Technological Systems

According to Hughes⁴⁷⁷, a technological system is both socially constructed and society shaping. The components of such a system are the *physical artefacts* (for example computers or TV satellites), *organisations* (as TV broadcasters or computer hardware manufacturers), *scientific components* (for example books and university teaching), and *legislative artefacts* (such as regulatory laws on ADSL provider's access to the incumbent's infrastructure or laws concerning advertisement in children's television programmes)⁴⁷⁸. Individuals are components of the systems, artefacts, by contrast, are the elements, which are *built* by the system builders⁴⁷⁹.

A system can be defined according to the perspective one wishes to apply. The system of interest might for example be a subsystem of a bigger system. Hughes also mentions the inclinations of different academic communities of defining systems in accordance with their own view – engineers are prone to limit a technological system to its technical components whereas neoclassical economists tend to treat technical factors as exogenous⁴⁸⁰.

A central aspect of Hughes' perspective is the often occurring battles that take place between system (with the battle between Edison's direct current and Westinghouse's alternating current as the arch typical example). When identifying the competition taking place between the systems of television and computer/networking, this perspective is obviously interesting.

Hughes identifies seven phases in the history of an evolving or expanding system: invention, development, innovation, transfer, growth, competition and consolidation⁴⁸¹ (where the three latter are not treated separately by Hughes), hereby increasing the detail compared to Schumpeter's three steps of innovation, diffusion and affirmation. Here, it is important to note, that the seven stages do not simply occur sequentially, as

⁴⁷⁷ Hughes, 1989, p.50.

⁴⁷⁸ Hughes also mentions natural resources as components of a technological system, and gives the example of coal mines. The only immediately obvious parallel within the topic of this project would be the bandwidth of the radio spectrum.

⁴⁷⁹ Hughes, , p.54.

⁴⁸⁰ IBID, p.55.

⁴⁸¹ IBID, p.56.

there is a considerable amount of overlap and back-tracking taking place between them.

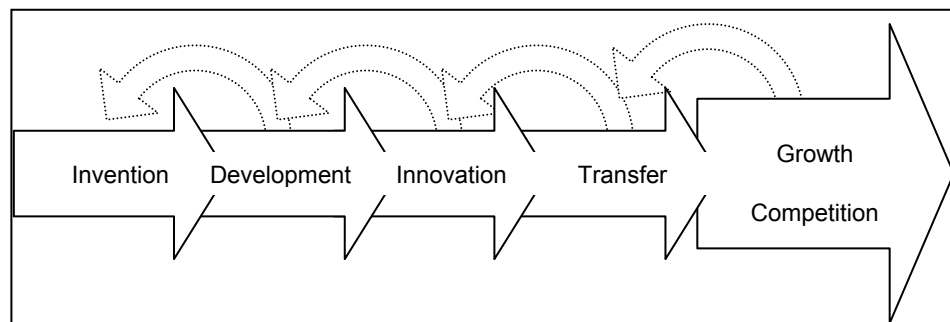


Figure 62: Phases of System Evolution (own graphic interpretation of Hughes' text).

Another important aspect of the phases is the roles of decision makers. In the phases of invention and development, the inventor-entrepreneurs assume important problem-solving roles, during innovation, competition and growth, the centre of gravity shifts to the manager-entrepreneurs, and in the consolidation and rationalization⁴⁸² phases, the important decisions are mostly made by financier-entrepreneurs and consulting engineers⁴⁸³.

Innovations basically come in two forms: radical and conservative innovations⁴⁸⁴. Here, Hughes' distinction resembles Schumpeter's notion of radical and incremental innovations, but also – however in less detail - Freeman's four levels of innovation⁴⁸⁵: incremental, radical, systemic and “change of techno-economic paradigm”.

The radical innovations inaugurate new systems – whereas the conservative ones rather are aimed at eliminating the so-called “reverse salients”⁴⁸⁶, a term which describes problems developing during the growth of a system. A reverse salient that cannot be remedied within an existing system becomes a serious problem, which may only be solved in radically different ways, thus bringing about a new and competing technological system⁴⁸⁷.

⁴⁸² Rationalization is not mentioned as a separate stage by Hughes, but is nevertheless included by him in the description of decision makes' importance.

⁴⁸³ Hughes, 1989, p.57.

⁴⁸⁴ IBID, p.57.

⁴⁸⁵ Century, 1999.

⁴⁸⁶ Hughes, 1989, p.73.

⁴⁸⁷ IBID, p.75.

Hughes introduces the concept of momentum⁴⁸⁸ (not to be confused with autonomy⁴⁸⁹), gained by technological systems after a period of growth and consolidation. Hughes seems to use the concepts of momentum and trajectory interchangeably, but – his case being electric power – does not take into account the network externalities occurring in the communication networks and hardware/software systems⁴⁹⁰. Focusing on the role of user and developer groups and individuals, he touches upon the mechanisms of gaining knowledge in the workings of a particular system. This is not surprising, considering his focus on the social construction of the systems.

Technological Paradigms and Trajectories

The convergence process displays certain similarities to the battle between competing technological paradigms described by Dosi⁴⁹¹. Compared to the works of Hughes, who goes into great detail concerning the workings of the particular systems subject to analysis, Dosi focuses more upon the paradigm shifts and competition than the actual development of them, and thus offers a more dynamic perspective upon the development on a more overall level.

The development of Dosi's concepts of paradigms and trajectories takes off in a criticism of the traditional market-pull and technology-push models, and especially focuses at the lack of these models of taking into account the feed-back mechanisms⁴⁹² occurring in the selection process (those described in the "Feedback and Externalities" section of the theory chapter). Rather than applying a traditional view, Dosi suggests the use of the concepts of technological paradigms and trajectories for describing the process of technological development. The notion of paradigms is inspired by Kuhn's⁴⁹³ work on scientific paradigms, to which Dosi draws numerous parallels.

⁴⁸⁸ IBID, p.77f.

⁴⁸⁹ Hughes states that "*Momentum, however, remains a more useful concept than autonomy. Momentum does not contradict the doctrine of social construction of technology, and it does not support the erroneous belief in technological determinism. The metaphor encompasses both structural factors and contingent events.*", Hughes, 1989, p.80.

⁴⁹⁰ This is not a problem in relation to this project, as these mechanisms are extensively treated in the "Economics of Standardisation" chapter.

⁴⁹¹ Dosi, 1982, pp. 147-162.

⁴⁹² IBID, p. 151.

⁴⁹³ Kuhn, Thomas S.: "The Structure of Scientific Revolutions", University of Chicago Press, 1970.

...we shall define a technological paradigm as a “model” or a “pattern” of solution of selected technological problems, based on selected principles derived from natural sciences and on selected material technologies.

Definition 33: A Technological Paradigm⁴⁹⁴ (a lexical definition).

The paradigm is brought about by an interplay between scientific advances, economic factors, institutional variables⁴⁹⁵ and unsolved difficulties in the existing technological path⁴⁹⁶ and moves along its particular trajectory, the latter being imagined as a cylinder in the multidimensional space defined by technological and economic variables.

We will define the technological trajectory as the pattern of “normal” problem solving activity (i.e. of “progress”) on the ground of a technological paradigm.

Definition 34: A Technological Trajectory⁴⁹⁷ (a lexical definition).

The four categories of “triggering factors” stimulating the emergence of (or a shift to) a new paradigm and its subsequent movement in the space defined by two variables can be graphically illustrated as follows.

⁴⁹⁴ Dosi, 1982, p.152.

⁴⁹⁵ The focus of this project being the compatibility and interoperability of appliances, and thus also the standards and authorities setting them, the institutional variables are considered an important shaping influence.

⁴⁹⁶ Dosi, 1982, p.147)

⁴⁹⁷ Dosi, 1982, p.152.

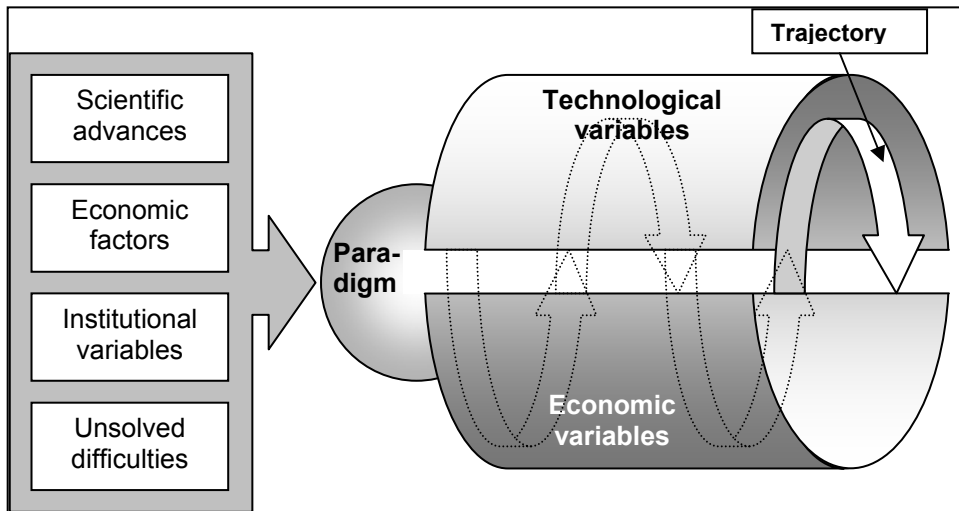


Figure 63: A technological paradigm and its trajectory (own graphic interpretation of Dosi’s article).

The paradigm and its trajectory display strong similarities with the systems proposed by Hughes (mentioned on page 88f.). Technological paradigms are prone to excluding technological possibilities coming from outside the paradigm itself. In accordance with Hughes, Dosi also stresses the high degree of momentum displayed by the selected path⁴⁹⁸. A further example of coherence among the two theories is the “unsolved difficulties” of Dosi, which strongly resembles the system shift inducing “reverse salients” of Hughes.

A number of important features of technological trajectories of separate paradigms can be identified⁴⁹⁹:

There might be more general or more circumscribed as well as more powerful or less powerful trajectories.

There are generally complementarities among trajectories... Furthermore, developments or lack of development in one technology might foster or prevent developments in other technologies.

In terms of our model one can define as the “technological frontier” the highest level reached upon a technological path with respect to the relevant technological and economical dimensions.

⁴⁹⁸ IBID, p.153.

⁴⁹⁹ IBID, p.154.

“progress” upon a technological trajectory is likely to retain some cumulative features.

Especially when a trajectory is very “powerful”, it might be difficult to switch from one trajectory to an alternative one. Moreover, when some comparability is possible between the two (i.e. when they have some “dimensions” in common), the frontier on the alternative (“new”) trajectory might be far behind that on the old one with respect to some or all the common dimensions. In other words, whenever the technological paradigm changes, one has got to start (almost) from the beginning in the problem-solving activity.

It is doubtful whether it is possible a priori to compare and assess the superiority of one technological path over another. There might indeed be some objective criteria, once chosen some indicators, but only ex post.

In the above, Dosi uses terms as “trajectories”, “paths” and “technologies” seemingly at random, and he might even use the term “paradigm” as well. One might interpret the above as having to do with *a number of trajectories adhering to each particular paradigm*, but this is not the case. It is the belief of this author, that Dosi suggests *one, and only one* trajectory per paradigm. This is supported by the fact that Dosi talks about the trajectory, not the possible trajectories of a paradigm.

Author's comment 4: Confusion about trajectories and paradigms.

Further adding a term to the multitude of trajectories, paths, technologies and paradigms, Dosi introduces the concept of an *industry*⁵⁰⁰. Two phases of development are presented. One is the process of search and selection on new technological paradigms, corresponding to the emergence of an industry. The other is the technical progress along an already defined path, corresponding to the maturity of the industry. While the first phase is characterised by the importance of institutions stimulating the accumulation of knowledge and experience plus risk-taking actors, the second phase is characterised by less turbulence and the attempts of more incremental improvements of products and services.

This distinction bears considerable resemblance to that of Schumpeter - (Usually referred to as the Schumpeter Mk I Vs Mk II conflict⁵⁰¹) which has to do with the effects of monopolistic and oligopolistic markets on the innovation ability. However, there is a noticeable difference, as Dosi claims that in both phases, the organised research and development efforts matter more than the initiative of individuals. A

⁵⁰⁰ Dosi, 1982, p.157.

⁵⁰¹ In his early works, Schumpeter favoured the entrepreneur as the important source of innovations, but later he changed his view to putting more emphasis on the oligopolistic companies.

further resemblance is noticeable, namely the works of David Teece⁵⁰², who distinguishes between the pre-paradigmatic and paradigmatic stages of an industry . The pre-paradigmatic stage is characterised by fluid designs and loosely and adaptively organised processes. After a period of time, one design begins to emerge, and once this becomes dominate, the industry has entered the paradigmatic stage, where competition shifts from design towards price.

Another parallel to the works of Schumpeter can be found in the shifts between paradigms. When an old paradigm – be it due to technical difficulties that can't be overcome or new technological opportunities – is abandoned in favor of a new one, a situation resembling the so called “creative destruction” phenomenon arises. According to Schumpeter⁵⁰³, a successful diffusion of an innovation can result in substitution processes leading a whole industry into a crisis characterised as "creative destruction".

The relevance of economics of innovation in convergence analysis

Though not used to any great extent for analytical purposes, the economics of innovation is an important body of supporting theory. Especially contributing with models that help understanding the dynamics of technological development, they assist not only to define the conceptual framework of this project, but also provide a basic understanding for the investigation and analysis of the convergence process and its involved systems. To conclude the section of economics of innovation, the following paragraphs describe two important aspects of the theories presented: their relevance in relation to the research problem of this project, and their usefulness in properly defining and analysing the converging areas in a well-established theoretic context – a usefulness not explored in this project, where this part of the economic theory primarily is used for descriptive rather than analytical purposes.

Dosi's heuristic proposal

In relation to the interpretation of technical change and innovation illustrated by paradigms and trajectories, Dosi presents a set of heuristic recommendations⁵⁰⁴, which are particularly interesting in relation to this project:

- Identification of the dimensions characterizing each technological paradigm and the differences between competing paradigms.
- Separation of the periods of “normal” technology from those of extraordinary search⁵⁰⁵.

⁵⁰² Teece, 1987, p.190.

⁵⁰³ Schumpeter, 1942, p.81f.

⁵⁰⁴ Dosi, 1982, p.161.

- Definition of the “difficult puzzles” and unsolved difficulties⁵⁰⁶ of a technology, which often trigger the search for radically alternative solutions.
- Description of the transition from one technological path to another – plus an assessment of the factors which allow the emergence of a winning technology.

When looking at the research questions posed earlier in this work, it is obvious, that they – though their formulation has not been inspired by Dosi’s heuristic proposals – have much relevance and to a great degree serve to shed light upon Dosi’s questions. A short presentation of the research question and their coherence with Dosi’s proposal can be presented as follows:

With reference to Dosi’s point 1: “Identification of the dimensions characterizing each technological paradigm and the differences between competing paradigms.”: This topic is treated by the conceptual questions of the theory chapter.

Concerning proposal number two, “Separation of the periods of “normal” technology from those of extraordinary search”, this topic is quite more difficult to examine within the framework of this project. This would be almost a historical study, which is somewhat difficult, as the process of convergence is taking place during the Ph.D.-project. The project admittedly contains a presentation of the history of television and other important developments, but apart from a study of the history of television in the appendix, it is not a historical study per se.

Regarding proposal three: “Definition of the “difficult puzzles” and unsolved difficulties of a technology, which often trigger the search for radically alternative solutions.”, the coverage by this project is somewhat backwards. As this project does not take off by identifying a number of problems, but rather chooses as a point of departure the actual status of the three systems, their properties and inherent characteristics, puzzles and difficulties are discovered *during* the analysis. Still, by identifying advantages and drawbacks of the various systems, the analysis touches upon areas that can be problematic to some of the systems. One could talk of an unsolved difficulty to the extent, that it is a problem for those operating within one system, if their competitors in another system can offer something out of the ordinary⁵⁰⁷. The research questions relevant to this proposal are those having to do with flexibility, the separation into hard- and software and the ability to incorporate quality-related innovations. Here, strengths of the computer networking system are sought, and hence, one could say that implicitly, the search is on for “difficult puzzles and unsolved difficulties in the television system.

⁵⁰⁵ Using Teece’s notion, this would be similar to identifying pre-paradigmatic and paradigmatic stages.

⁵⁰⁶ Using Hughes’ concepts, this is equivalent to searching for “reverse salients”.

⁵⁰⁷ E.g. a news provider on the internet can offer a high degree of interactivity, a news provider from the television system can only offer so called “carousel interactivity”.

The last of Dosi's proposals, the "Description of the transition from one technological path to another – plus an assessment of the factors, which allow the emergence of a winning technology" are to a large extent addressed by the research questions in the "Research problem" chapter.

The second part of the proposal – an assessment of factors allowing for the emergence of a winning technology – are more or less implicit in the whole Ph.D.-project. This can for example be illustrated by the question and considerations in the introducing sections of the "Research problem" chapter.

Dosi's heuristic proposals are – though presented two decades ago – highly topical for application to the area of convergence of infocom. Though they have not in any way guided the formulation of research questions for this project, it is satisfactory to establish, that the research problem of the project is in accordance with this important body of theory.

The TVPC Proof-of-Concept Prototype

As is the case of all three case studies of this Ph.D.-project, practical experimentation, configuration and prototyping is carried out in relation to the cases for the purpose of gaining practical experience in the case topic. Where the two other proof-of-concept prototypes actually prove that a particular form of infocom is possible and perhaps even viable, this particular piece of work is less of a prototype. In order to maintain coherence in the project, having three proof-of-concept prototypes, each relating to a case study, this chapter is nevertheless labelled as a proof-of-concept prototype.

Purpose

The aim of the practical work with TVPCs has been to plan, build and configure PCs, which can do the tasks usually undertaken by a TV set and a VCR. Furthermore, the work was intended to give the author insight into the opportunities of adding further functionality to the TVPC than that of traditional TV appliances.

There is, however, *not much concept to prove*, as many users already use their PC for TV purposes⁵⁰⁸. There already exists a wide variety of hard- and software undertaking the tasks, which are the focus of these experiments. The experiments with TVPCs have thus been focussed on gathering hands-on experience for the case study rather than proving that TVPCs actually do work. Much of the knowledge gained is used directly in the analysis of hardware, software and services in the TVPC case study. The findings of this work are implicit in the elaborate descriptions of hard- and software in the case study. Therefore, this chapter is short, and only presents the actual pieces of hard- and software that have been subject to experimentation.

Hardware

A number of TVPCs have been built and configured during this project. Due to the switching and swapping of hardware between computers, it is not possible to define particular TVPCs in the experiments. The following presentation of the hardware used thus focuses on the single components rather than whole computers.

The hardware used for experimentation was traditional desktop computers. The components were ordinary motherboards, RAM, AMD or Intel CPUs and ordinary CD-ROM, CD-R and DVD drives for storage. For capturing video, cheap IDE hard disks were used. SCSI hard disks and IDE RAID configurations were installed, but as

⁵⁰⁸ A very experienced and advanced group of users, some of whom are developing TVPC software themselves, are organised at the online AVSForum's Home Theater Computers Special Forum Area at: <http://www.avsforum.com/avs-vb/forumdisplay.php?s=d123b6db38946738e09815fbdca40c2&forumid=26> - Online reference – link active per 020717.

one IDE hard disk proved sufficiently fast in most cases, the more advanced hard disk installations were never put to much use.



Figure 64: Computer cabinet – the humble home of the TVPC⁵⁰⁹.

The more specialized components necessary for adding TV functionality to the computer were sound cards with the ability to output 5.1 channels, graphics cards with the ability to input and output analog video through composite or s-video and - being the most crucial type of component - TV tuner cards. The marks and models used for experimentation are described in the following.

Sound Cards

Two different makes of sound cards were used for the experimentations. All the cards were selected for their ability to output 5.1 channel analog audio. Some were even able to output a digital signal to an external amplifier with built-in decoder.

One of the cards, the Terratec Soundsystem DMX worked well under Windows98, but at the time of experimentation, no drivers for Windows2000 were available. This greatly reduced the value of this otherwise well functioning card, which had a wide range of digital as well as analog output capabilities.

⁵⁰⁹ Picture from the Codegen Group website (online reference:
<http://www.codegengroup.com/proddetail.asp?id=119> - link active per 020717)

A couple of sound cards from the market leader Creative Labs were also put to use. Being more up to date with respect to drivers for the various operating systems, these cards were easier to use. The Live! Platinum 5.1 came with digital as well as 5.1 analog output, being a very versatile but expensive card. A cheaper, more recent, alternative was the Creative Soundblaster Audigy Gamer with 5.1 analog audio. Lacking digital output, it is a less versatile card, if the aim with a TVPC is having the computer doing the decoding by software⁵¹⁰, this is a cheap and well functioning sound card for the purpose.

Actual tests of the sound quality were not carried out, as it is highly dependant of the connected amplifier and speakers – components, which is outside the scope of this chapter.

Graphics Cards

Only one mark and model of graphics card was put to the test. This was the ASUS AGP V6800 Deluxe. As all graphics card, it had a VGA port, which can be used if one wishes to view TV on the computer monitor or a projector. Furthermore, it had TV-in-and output, the former making it possible to display the computer image (and hence the TV picture) on a TV set via a composite or S-Video cable. The latter connection – the TV-in – gave the possibility of connecting external television sector appliances such as VCRs or satellite set-top boxes, also via composite or S-video. While working flawlessly, this latter opportunity was not explored further than to establish the actual functioning of this feature.



⁵¹⁰ Software decoding is a more future-proof solution than decoding by stand-alone hardware or on-board dedicated chips, as observed in “The TVPC Case Study”.

Figure 65: ASUS AGP V6800 Deluxe graphics card with video in and out⁵¹¹.

The TV-out functionality was of very poor quality, yielding a blurred picture with black bars on all sides, thus not utilizing the full screen area of the TV set. This is known to be a common flaw of the NVidia TV-out chips used by this manufacturer, and it is claimed, that graphics cards of the brands ATI and Matrox are superior in the area of outputting to TV⁵¹².

Tuner Cards

The one crucial component adding TV functionality to the computer, making it a TVPC, is the tuner card. These experiments have been concerned with two basic types: Digital satellite based DVB tuner cards and analog terrestrial/cable cards. Both connect to the signal sources in the same fashion as traditional TV appliances, i.e. through coaxial cables.

The workings of the analog cards are quite trivial, as they have been available for around a decade. Most are based on a Brooktree 848 or 878 chip, and they have not changed in any major respect during the last year. The analog card used for the TVPCs was the Hauppauge WinTV Go, which worked in many configurations without problems. The only drawback of this card was, that it delivered mono sound only, making it impossible to try out the Dolby ProLogic surround sound delivered by a number of TV stations.

The Digital DVB satellite cards that have been fitted into the TVPC were the Kiss Satdem CI and the Hauppauge WinDVB-S. Both were quite similar cards with a Common Interface module, allowing the viewing of pay channels when a subscription smart card was inserted into the module. Again, both cards worked flawlessly, the only problem being, that the TVPCs often were turned off during the TV stations' update of codes. This made the subscriber smart card stop working, and it had to be inserted into a traditional satellite set-top box to be activated. This problem is not existent on a traditional satellite tuner box, which usually is left in stand-by mode while not used. Computers, by contrast, are usually shut down after use – a practice which must be abandoned if one wants to use it for viewing of subscription satellite channels.

⁵¹¹ Picture from Tom's Hardware Page (online reference:
<http://www.tomshardware.com/graphic/00q2/000406/geforce-01.html> - link active per 020717)

⁵¹² Again, the online AVSForum's Home Theater Computers Special Forum Area at:
<http://www.avsforum.com/avs-vb/forumdisplay.php?s=d123b6db38946738e09815fbdca40c2&forumid=26> is the main source of this information. Online reference - link active per 020717)

While the analog TV tuner card had a wide variety of 3rd party software options, the digital satellite cards were only usable with the accompanying software, hereby greatly reducing the variety of opportunities. Later, 3rd party software for DVB cards have arrived, as mentioned in the TVPC case study on page 181, but this was not available at the time of experimentation.

The hardware components of the TVPC offer little challenge by themselves. All the hardware included in the experiments has proven to be compatible with traditional motherboards, making for relatively easy installation. It is, of course, somewhat more complicated than connecting an antenna cable to a TV set, but it should not deter the average computer user.

Software

As is the case of the hardware, the software used for the TVPCs was quite common – the only necessary pieces being an operating system and the TV tuner card software.

Operating systems

A number of different operating systems (including Linux and Macintosh) can be used for television viewing on computers, but the focus of computers in this project is the so-called Wintel computers, using Windows operating systems and Intel (and also AMD) CPUs.

A number of Windows operating systems have been installed on the TVPCs. Among these, the professional variants, Windows 2000 and Windows XP, proved to be most stable. Windows 98 was also installed, but appeared prone to crashing on many occasions. As the TV tuner card software delivers the main television functionalities, the operating system is not a very conspicuous part of the TVPC, stability being the most important aspect.

Tuner card software

As is the case with hardware, the most crucial piece of software of a TVPC is the one that controls the TV tuner and displays and records the television content. All of the pieces of software described in the TVPC case study have been installed and tried out.

For pure TV-viewing, DScaler has proven to be the most sophisticated piece of software, yielding a superb picture quality, furthermore providing teletext viewing with great ease, as all pages are cached, making for easy and fast access without the waiting time known from TV sets. Lacking a proper recording functionality, it does however not serve all purposes of a TVPC piece of software. Here, a number of alternatives such as ShowShifter, SnapStream and IUVCR have been installed for evaluation. They all offer a wide range of options in the areas of choice of codecs and

compression when capturing video to the computer's hard disk. They share the common feature, that they are programmable, so that recording can be set in advance, and (though only for some countries) ShowShifter and Snapstream even integrate with online TV-guides for one-click recording settings, as described in the TVPC case study.

Apart from the 3rd party software, most tuner cards come with software developed by the manufacturer. These do not match the above-mentioned software in terms of versatility. One feature, however, deserves to be mentioned here: Hauppauge's WinTV2000 software allows exporting of teletext into word- or text documents or spreadsheets for considerably more convenient viewing than the coarse fonts of traditional teletext.



Figure 66: Hauppauge VTPlus teletext export facility⁵¹³.

An important and often troublesome issue of the software and drivers for tuner cards is the support of VFW and WDM. Both are application programming interfaces (APIs) of the Windows operating systems, allowing the displaying and capturing of video and audio content. VFW (Video For Windows) is an older API, which has been supplemented by the more efficient WDM (Windows Driver Model) from Windows 98 and onwards⁵¹⁴. Using the newer and better WDM API is, however, the source of much frustration among users. Though it is supported by all the TV tuner card software presented in this chapter (IUVCR actually *only* supports this API and not VFW), the present state of WDM drivers for the tuner cards leaves much to be desired - as the ShowShifter technical support puts it: "...some manufacturers WDM drivers have proved to be a little flaky...". The experiments carried out with the TVPCs have

⁵¹³ Hauppauge Computer Works, Inc., p.55.

⁵¹⁴ Microsoft Corporation, 2001.

shown, that this is particularly the case for PAL drivers used in Europe and Australia, while WDM drivers for the North American NTSC system are more mature.

The software components of the TVPC are numerous. Apart from the operating systems and TV tuner card software mentioned here, the user has to choose drivers for the tuner card, and furthermore – when recording – select a codec and choose compression settings. The software and settings can be combined in many ways, some of these leading to poor performance or crashing. It is often necessary to undergo a process of trial-and-error to achieve a well-functioning setup.

Conclusion

The experience of this “proof-of concept prototype” is, that in order to configure a well-functioning TVPC, much effort has to be devoted to the processes of experimentation, error detection and troubleshooting. Unless one has a considerable interest in - and knowledge of - computers, the prospect of designing an appliance for TV consumption based on the traditional desktop computer is not an attractive one. In the present situation, with faulty drivers and a multitude of combinations of software and hardware, many will be better served with traditional TV appliances.

However, if one – as is the case of this author – is fond of experimenting with computers, the outcome of a TVPC design and configuration process can be very instructive, and the final outcome can be an appliance which by far surpasses the traditional TV appliances in terms of quality and versatility. If the software, drivers and codecs continue to mature in the future, these benefits will be available to a larger audience than today.

The MultiModality Proof-of-concept Prototype

This chapter presents the work in relation to the modality case. It explains, how the possibilities of consumption of stereoscopic video and computer animations were explored. The possible technical solutions for the different modalities are described, and the paths followed are explained. Furthermore, possible solutions to the problems of “household stereoscopy” are presented. The following sections are based upon the web site⁵¹⁵ developed by this author for presenting the modality experiments in relation to this Ph.D. project, where some adjustments have been made in order to make the text more suitable for this dissertation.

Background and purpose

The idea of the multimodal room is to explore the possibilities of various forms of sensory inputs in interaction with computers, television, video etc.

The room is a test bed and demo room for different ways of increasing visual, additive and tactile perception in entertainment, communication and computer interaction. This added sensory perception centers around the following topics:

Visual: Adding depth perception to the visual input by use of stereoscopic technologies.

Auditive: Adding a feel of orientation to the auditive experience by use of surround sound technologies.

Tactile: Adding sensory input to hands as well as the whole body by use of actuators and force-feedback devices.

In addition, the room has the obvious capability of displaying traditional media without added sensory input. As such, it serves as a traditional small cinema and presentation room. It can be used for showing, among other things, television programmes, stereoscopic video tapes and stereoscopic computer games.

⁵¹⁵ www.stereoscopy.cti.dtu.dk - link active per 020701.

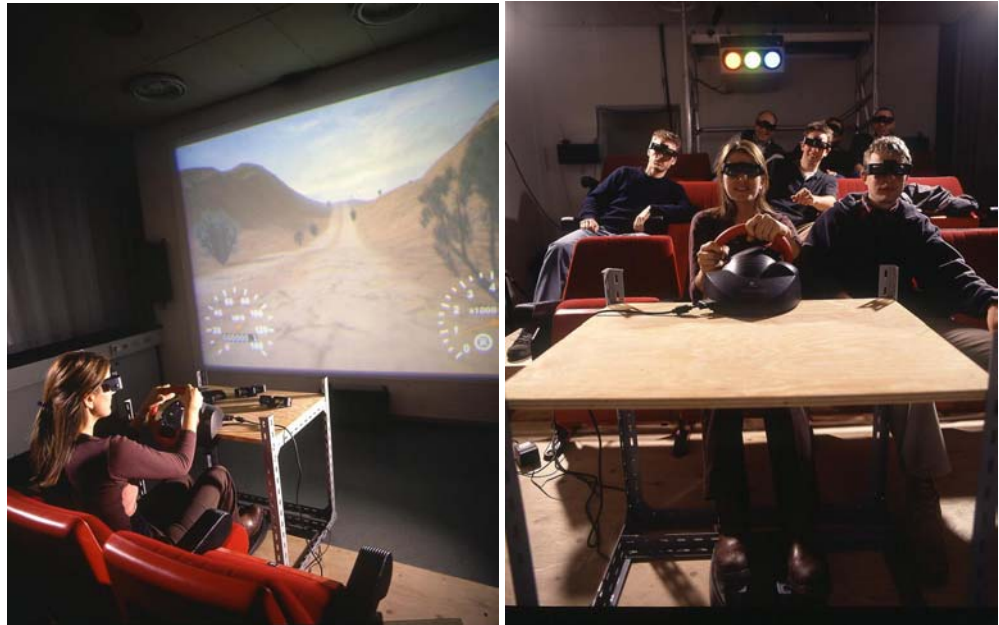


Figure 67: The multimodal room - for multiple purposes, including driving simulation⁵¹⁶.

History

The first concerns when establishing the multimodal room were the visuals. It was fairly clear, that the most important improvement in this field was adding depth perception to the view. Since the introduction of colour television in the 1960s, stereoscopy is a good candidate for the most important innovation in display technology.

Another candidate for most important innovation could be head tracking: the changing of the image in accordance with the user's head movements. This innovation is however most relevant in the field of HMDs (Head Mounted Displays), because the screen would have to follow the user for head tracking to be relevant⁵¹⁷.

As one of the purposes of the multimodal room is demonstrating various forms of content and technologies, the thought of HMDs – and consequently head tracking – was abandoned. The HMD is a strictly personal piece of equipment, while all viewers share the white screen of the multimodal room.

⁵¹⁶ Photos by Karsten Damstedt.

⁵¹⁷ There's not much point in changing the picture on a screen that the viewer is looking away from, when he turns his head.



Figure 68: Projection screen being mounted.

Visual

When wanting to display stereoscopic content projected on a screen, two basic methods of separating the right and left eye images exist:

One projector with shutter glasses using page-flipping source format.

- Pros: good image quality
- Cons: complex and expensive – projector as well as glasses.

Two stacked projectors with polarisation filters and demultiplexer (a small box with circuitry separating right and left eye's images from a page flipping source signal).

- Pros: acceptable image quality, smaller equipment, projectors commonly available. Inexpensive glasses – can be given away for free.
- Cons: complicated setup of projectors and demultiplexer. Expensive demultiplexer. Special non-depolarising screen is necessary.

Having settled on shutter glasses as the basis separation method, a number of suitable projector types were examined. When using shutter glasses, the displayed images must alter between the images for left respectively right eye at least 100 times a second. If not, the synchronized flickering of the glasses will be visible to the viewer, leading to discomfort and in some cases seizures. Consequently, a minimum of 100 Hz refresh frequency was a basic requirement.

LCD projectors

The first attempts of large screen stereoscopic display was done at traditional LCD (Liquid Crystal Display) projectors in mid 1999. Initially, it was obvious, that the images displayed for left respectively right eyes by the projectors were out of sync with the shutter glasses. After some investigation, it became clear, that LCD projectors were too slow in switching between images (a phenomenon known as latency or afterglow).

DLP projectors

The next path explored was the so-called DLP (Digital Light Processing) projectors. This type of projector resembles a LCD projector on the outside, but utilises a fundamentally different principle when generating images. Theoretically this technology would be perfect for use with shutter glasses.

However, field tests proved, that the images displayed tearing effects – or became “jerky” - when attempting to display stereoscopic video or computer graphics. After consulting Davis, a Norwegian DLP projector manufacturer, the problem was identified as coming from the projector’s internal frame rate converter. This converter forced the projector to display the output at a fixed frequency (e.g. 60 Hz), regardless of the frequency setting of the computer’s graphics card. The latter controls the shutter glasses that therefore were out of sync.

Some models of DLP projectors are claimed to be without internal frame rate converter and should as such be suited for use with shutter glasses. Sporadic field-testing was undertaken, but all projectors seemed to display the same problem as those with internal frame rate converters.

The future might prove that DLP is the way to go, but this path was abandoned in search of an older and more tried method.

CRT projectors

After unsuccessful attempts with LCD and DLP projectors, the focus was turned towards the rather old fashioned CRT (Cathode Ray Tube) technology.

Initially, a solution based on a CRT projector was avoided, as these projectors are expensive, complex and bulky. It turned out, however, that it was the only suitable type of projector available.

Initial tests were made with an old BarcoData 600 CRT projector. Many hurdles had to be overcome before a stereoscopic image could be displayed. For example, a sync converter had to be constructed, combining the horizontal plus vertical separate sync signals of the computer into one composite sync signal accepted by the projector. Unfortunately, this old projector was unable to display at a resolution higher than 400x300 at the minimum acceptable frequency of 100 Hz. Practically speaking, this projector helped demonstrate that CRT was a viable path, while the projector itself was incapable.



Figure 69: BarcoGraphics 808 projector, scaffold and cinema seats.

By late 1999, a newer CRT projector – a BarcoGraphics 808 – was purchased. In comparison, this projector is able to cope with much higher resolutions and refresh rates than the Data 600, and in addition it has a much easier system for setting the geometry of the tubes. On the downside, it weighs around 100 Kg. The Graphics 808 needs a special interface box for accepting a computer signal. Originally, it came with an Extron 118 RGB Plus interface, which worked flawlessly. Unfortunately, the interface's power supply broke down, and the supplier replaced it with an inferior

Inline 2001 interface, which has difficulty coping with the high refresh rates needed for stereoscopic viewing⁵¹⁸.

The purchase of such a high-quality, expensive projector plus the scaffold on which to hang it, warranted better seating facilities for the audience. Therefore, a number of used cinema seats were purchased, and wooden steps upon which to mount the seats were constructed.

Auditive

On the sound side, original experiments were limited to computer sound systems as e.g. Creative Labs' Environmental Audio. As the whole case is part of a Ph.D. thesis focusing on the convergence between old and new forms of communication and entertainment, it soon became clear, that a sound system capable of generating surround sound from the television and cinema world was necessary.

To satisfy both the need of a multi-format surround sound system, an Onkyo receiver/amplifier was purchased. This amplifier is able to decode the Dolby Digital and AC3 surround formats used by cinemas and DVD players, and has in addition the ability of transmitting the multi channel surround sound from a computer (e.g. Creative Labs' Environmental Audio) to its speakers.



Figure 70: Front and back of the cabinet containing computer and surround receiver.

The speaker set is a so-called 5.1 setup with a front left, right and centre speaker, a rear left and right speaker plus a subwoofer.

⁵¹⁸ In October 2000, negotiations with the supplier concerning a better replacement interface were carried out, but to no avail.

Tactile

The first force-feedback device tried was a Logitech Wingman force-feedback joystick. It was used with computer games, as they are the form of content most developed in the field of force-feedback⁵¹⁹. It worked well, but it was obvious that further tactile input was desirable.

For the purpose of adding further reality to car simulator software (which proved very suited for stereoscopic viewing), a force feedback steering wheel and pedals were purchased. They – as the joystick – are fed with force-feedback information defined by the application (in this case, the computer game) through the game or USB port of the computer.

A more experimental step was taken with the purchase of an Aura actuator. This device is basically a loudspeaker unit with a heavy iron weight instead of a membrane. Instead of emitting sound, it vibrates. The actuator (or shaker, as it is popularly referred to) was mounted on a go-cart seat in a rig containing the wheel and pedals). The shaker was fed with the low frequencies of the game's sound, amplified by a Denon amplifier set to max. bass and min. treble.



Figure 71: Aura actuator mounted under cinema seat.

⁵¹⁹ There have been attempts of building “earthquake equipment” in cinemas for the purpose of adding reality to the “disaster” category of movies, but no widespread system for tactile input has been developed in the area of television and movies.

As cinema seats were put in the room, the rig went out – and the shaker with it. A smaller console for wheel and pedals has been constructed, making it possible for the “driver” to sit in the right middle front row seat. The shaker is mounted underneath this cinema seat.

Olfactory

Another sense relevant for the feeling of presence is smell. Development of scent emitters is ongoing, but no devices enabling the user to for example smell the petrol or burnt rubber when driving a car simulator are currently available.

To add some feeling of being inside a car when using a car simulator, a so-called Wunderbaum has been purchased. This, however, was not seriously meant as a means of adding feeling of presence, but rather as a constant reminder that there are more senses open to influence than the three mentioned above.

Equipment

As of October 2000⁵²⁰, the equipment in the multimodal room is the following:

BarcoGraphics 808 CRT projector

Inline 2001 RGB adapter box

Wall mounted white screen

Onkyo TX-DS777 surround amplifier

JAMO THX 5.1 surround speaker set

Aura shaker w/Denon PMA-715R Amplifier

Logitech Wingman Force joystick and Logitech Wingman Formula Force steering wheel and pedals

6 pairs of I-Art EYE3D wireless shutter glasses

2 pairs of ASUS wired shutter glasses

One Wintel PC with ASUS V6800 Deluxe graphics adapter (with own driver plus ELSA generic stereo driver).

⁵²⁰ Per July 2002, no major changes have been made. Some experimentation with dual projector configurations with polarizing filters has been carried out, but without conclusive success.

15 cinema seats mounted on a podium in three descending rows.

In addition, various pieces of hard-and software - among them Nu-View stereoscopic camera adapter - are part of the multimodal room.

Conclusion

The reason for establishing a room dedicated to these experiments is the intention to prove that, within a household budget, it is possible to select and combine a set of appliances giving the user a rich modal experience. With the prices and complexity of the equipment well exceeding that of household computers and TV sets, the multimodal room has proven, that this is *not* possible. The experiments carried out during the development of the multimodal room have nevertheless been invaluable in relation to the modality case study. Much experience has been earned during the configuration and experiments, and having actually established the multimodal room has made it easier to estimate what is necessary in order for the promise of quality to come true.

One cannot with certainty categorize the multimodal room as a prototype. All the phenomena (e.g. CRT projectors with shutter glasses, surround amplifiers for use with computers, tactile feedback by the use of actuators) have been seen before. Using all these facilities in combination, however, has not been seen elsewhere, apart from comparably expensive installations in theme parks.

Future development

Establishing and using the multimodal room has given inspiration for a number of innovations in the field of added modality. Two particular solutions have become obvious in aiding the usability and adoption of stereoscopy in a large group scenario of usage:

- Stereoscopic adapter for LCD type projector – splitting the image of one LCD or DLP projector into two for displaying stereoscopic content in above-below format.
- Dual webcam setup – mounting two webcams and capturing their video into one video stream or file, for example in side-by-side format. This would make stereoscopy usable in two-way communication.
- Stereoscopic driver for graphics card with dual VGA output - making it possible to output a variety of stereoscopic formats from one computer to two projectors, each projector showing one eye's perspective, and separating right and left eye's views by means of polarization rather than shutter glasses.

Among these suggestions for future development, the first (concerning the adapter for a projector) was formulated further in the sections below. The work of designing the optics necessary was carried out as a mid term project by two students at Department of Physics at DTU under supervision by Erik Dalsgaard. No actual prototype was constructed, as the mid term project concluded that – while technically possible – the adapter would be very complex, bulky and expensive, and thus not suited for production. The initial specification and requirements to the adapter can be seen as a separate document in the appendix.

Short experiments were done with capturing the video of two webcams connected to the same computer. Firstly, it proved impossible with traditional drivers to have the computer recognize both webcams. Secondly, an application capturing both streams and merging them into one in real time could not be found. Focus was directed towards mounting a lens- or mirror based image-splitting device on one camera. While this considerably simpler solution seems more viable, further experiments have not been carried out due to time constraints.

The third (dual VGA) solution suggested above has been explored further by a number of stereoscopy enthusiasts (including this author), in the online forum at the Stereo3D website⁵²¹. Though a number of drivers have been developed which, under certain circumstances, yield separate perspectives from the VGA ports of a dual VGA graphics card, no robust and practically usable solutions have emerged.

Among the solutions pursued were:

- Using the Win3D stereoscopic library with the VRCaddy driver – This solution should work according to Win3D developer David Qualman⁵²², but no successful implementation is known.
- Using native OpenGL stereoscopy with GeForce Quadro graphics card⁵²³. This solution works, but only for a limited number of consumer applications – most notably the first person shooter game QuakeIII Arena.
- Using the stereoscopic video card driver plus Nview display management tool (both from graphics chip manufacturer Nvidia Corp.). By setting the Nview mode to clone and the refresh rate to 60 Hz, this can be achieved. This solution is not quite stable and only works with Direct3D applications (i.e. *not*

⁵²¹ The Stereo3d.com Webboard: <http://www.stereo3d.com/discus/> - link active per 020710.

⁵²² Qualman, 2001.

⁵²³ A discussion of how to achieve this can be found in this article: ToxicX (real name of author unknown): Stereoscopic OpenGL and NVIDIA 3D cards guide, the StereoVision.net website, October 2001 (online reference: <http://www.stereovision.net/articles/nvidiaopengl/nvstereoogl.htm> - link active per 020711)

OpenGL applications). However, it is the most promising of the three possible solutions.

These suggestions apply to computer generated content such as VRML environments and computer games. The other major category of content, stereoscopic movies, is easily playable with twin projectors on a dual VGA-out card. By expanding the video player application's window onto both desktops, side-by-side as well as above/below stereoscopic video can be made to fit the projectors perfectly, displaying left eye's perspective on one projector and right eye's on the other.

The ease of playing stereoscopic video on such a configuration plus the promising, though not complete, development of suitable drivers for computer generated content makes this a promising future solution. If DLP projectors continue dropping in price and the expensive demultiplexer can be avoided by methods as those just presented, this can be an affordable and usable configuration for private users.

The Hybrid Communication and Information Proof-of-Concept Prototype

Early in the PhD-project, in the spring of 1999, the TVBoost service was developed, partly to get hands-on experience in the overlapping area between television and Internet, but primarily to prove that it is possible to enrich television broadcasts with Internet content.

This prototype has a strong connection to the Hybrid Communication and Information Case Study, as it proves, that many of the concepts treated in this study are absolutely viable, and even easily manageable by almost anyone wishing to deliver supplementary services of this kind.

This chapter explains the development of the TVBoost prototype, the organisation of the site itself, and shows the introductory pages of the site guiding viewers through the necessary steps.

The TVBoost service

The experiment consisted of a website, which could be viewed on top of the television picture. It was intended for use on a TVPC, but depending on its capabilities, a stand-alone Internet capable set top box might have worked as well. For the TVPC to benefit from TVBoost, the computer should have a TV tuner card installed (to receive the TV signal), and an Internet connection (to receive the information on the TVBoost website).

The TVBoost website was quite ordinary in its construction. Apart from normal HTML content and graphics files, two Java scripts⁵²⁴ were used: “Full Screen Window Opener Script”, to open the html page with the menu bar in full screen, thus avoiding the traditional browser window with all its buttons and text, and “Sliding Menu Bar Script IV” to generate an animated menu that appeared when the mouse cursor was moved to the left edge of the screen.

The topic of the prototype service was the Tour de France of 1999. For each day during the race, the website was updated with the latest overall standings, as well as the various competitions in the race and yesterday’s stage results. The information on the site was of the kind, that the event’s producer would choose to display on screen with shorter or longer intervals⁵²⁵. With TVBoost, viewers could view the information when they desired, rather than waiting until the producer found it appropriate to display the information.

⁵²⁴ Both downloaded from the Dynamic Drive website at www.dynamicdrive.com.

⁵²⁵ Not necessarily intervals suiting the taste of viewers.

From the menu bar appearing, the user could choose between a variety of information, which would appear when the mouse cursor was placed on the left edge of the screen.



Figure 72: TVBoost window with menu visible.

This menu contained clickable links to particular pieces of information, which would appear in semi-transparent form in the middle of the screen. Viewers could choose to see the results of the last stage, the overall standings, the mountain and points competition standings, and stage profiles from the Eurosport website⁵²⁶.

To add a further aspect of communication – referred to as “many-to-many” in the taxonomy - a chat feature was added. Hereby, viewers could log on to a chat service and exchange observations and comments with other viewers in real time.

As can be seen form Figure 73, the readability of the information from the TVBoost website was far superior to that obtainable by the use of teletext. This is partly due to

⁵²⁶ This phenomenon is called *deeplinking*, and is a controversial topic today, as it is – by some – regarded as a form of theft to display the content of other websites as if they were one’s own. Stage profiles specifically for the TVBoost website were under development at some time, but were abandoned as they were very labor intensive to create.

the superior quality of computer monitors over TV sets, but mostly due to the many possibilities of graphics, different fonts etc. that exist within the html standard.

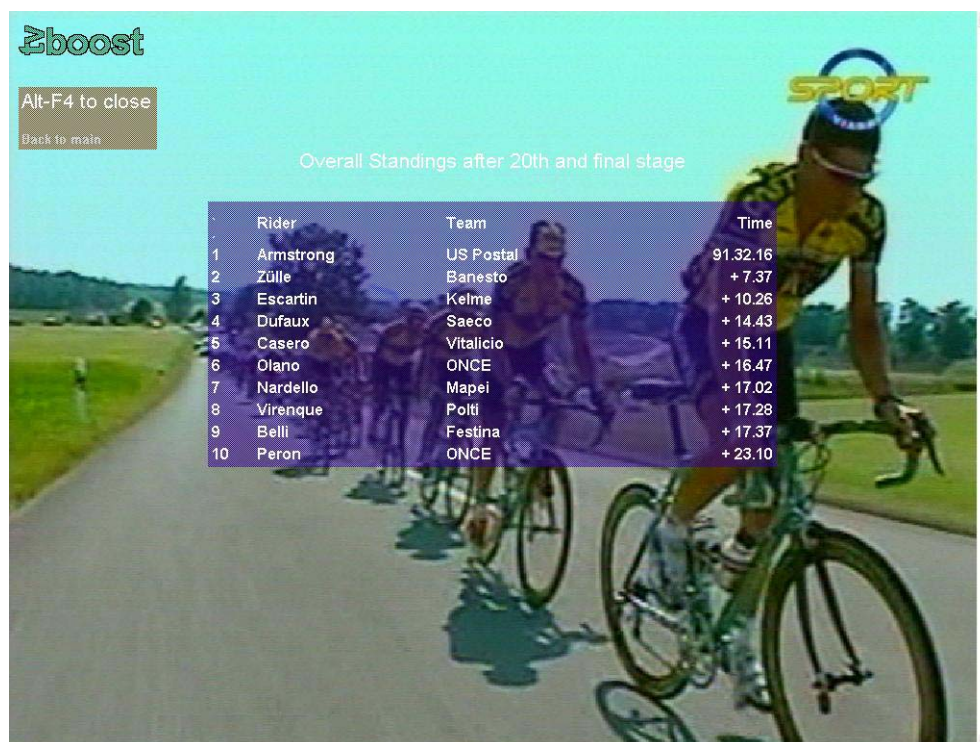


Figure 73: TVBoost window with "Overall Standings" information in semi-transparent frame.

Being updated on a day-to-day basis, there were many forms of information, which were not included in the prototype. For example, when riders break away from the main pack, it is useful to the viewer to know the size of the current time gap between the breakaway and the pack. The event's producer - usually with long intervals - provides this information. An option for the viewer to bring up a graphical representation of the time gap at any time would have been an extremely useful feature. Unfortunately, this would require access to the information controlled by the event's producers. This information is not likely to be available to private individuals desiring to contribute information, but for an organiser of an event (such as in this case the Société du Tour de France), adding such information into a website such as TVBoost could add considerable value to their product.

Technical Issues

As indicated earlier, the website delivering the TVBoost service used only the fundamental html features common even to hobbyists. The site was hosted at the web server of Center for Tele-Information at DTU in a simple hierarchical structure containing folders for the specific tables of information, the obsolete information and the graphics elements.

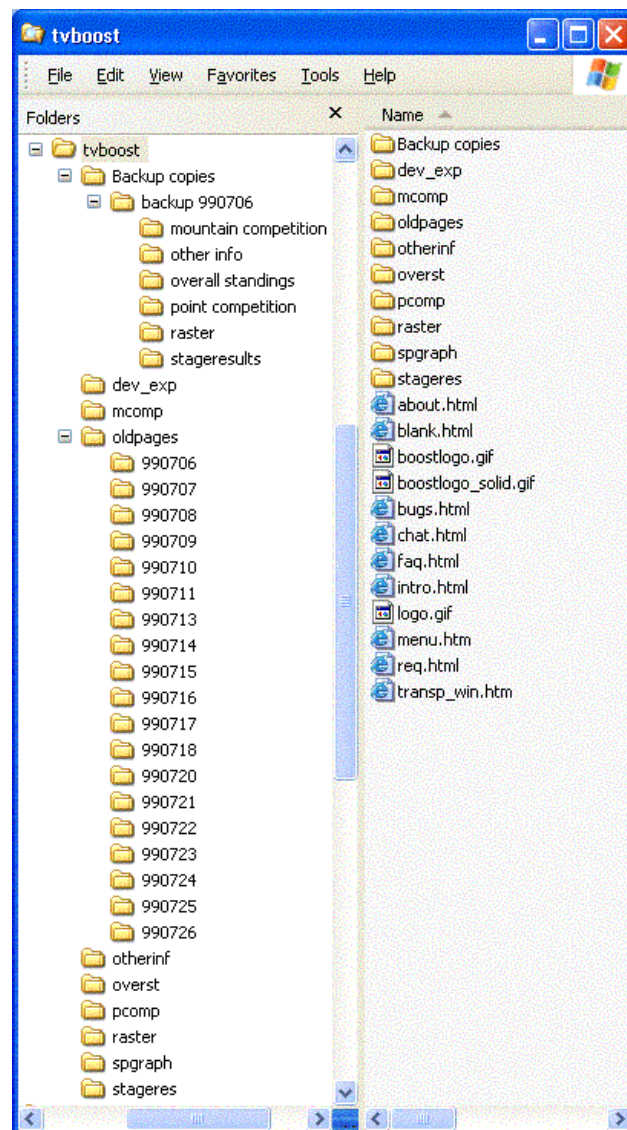


Figure 74: Structure of the TVBoost website.

HTML programming, layout, designs of logo and raster backgrounds were done by this author. Only the Java scripts were developed by somebody else.

In 1999, the browser war was still raging, with Netscape Navigator and Microsoft Internet Explorer as the main contenders. The Java scripts were chosen for their ability to work which each of the two major browsers at the time. They do, however, work more smoothly on Internet Explorer than on Netscape. Extensive searches for smoothly-working scripts for both browsers were conducted, but without success. The situation already in 1999 was that there were considerably more Java Scripts available, designed primarily for Internet Explorer. By choosing a script working better on Internet Explorer, the TVBoost website unintentionally aided in securing the domination of this browser. By delivering a complementary asset more suited for the installed base of Microsoft's browsers than that of Netscape, it – however insignificantly – took part in the positive feed-back leading to the victory of Internet Explorer⁵²⁷.

The TVBoost Website

The following sections (until the conclusion of this chapter) consist of text from the TVBoost website. It provides a pathway to the service itself, introduces to the rationale behind it, and explains how to use the features.

Welcome

Welcome to TVBoost - an interactive hybrid service developed by Alexander G. Øst at Center for Tele-Information.

TVBoost combines the benefit of traditional television with the flexibility of the Internet. Being an experiment, this version does not explore the full potential of the service, but does however deliver slightly more than a tekst-tv or captioned text system.

The test event is the Tour de France. The service is daily updated standings and quick links to Eurosport's stage profiles. In future versions, many forms of additional information can be imagined. In the test case - bike racing - for example rider and team profiles, zoomable stage profiles, rider positions via GPS, thumbnail videos from additional cameras.

After this short introduction, let's move on to the pages themselves. To use the site, you must have a windows PC with Internet access and a TV tuner.

Now, turn on your PC's TV tuner window (set it to full screen) and having already opened this page in your browser, you press the "Open window" button below.

⁵²⁷ Internet Explorer is not the only browser available today, but over the last couple of years, it has gained a market share so impressive, that few leave the competitors any chance of prevailing.

Now a transparent full screen window opens. On the left, you'll find the menu bar.



Remember to press Alt-F4 to close the transparent browser window.

About TVBoost

TV overlay - a hybrid service

This project is the result of considerations regarding the appropriate use of different communication networks. Basically, it combines two forms of information distribution: The real-time spreading of video signals via broadcasting and the specialised delivery of requested information via the internet.

TV overlay is an attempt to successfully combine these two communication forms - so that the information which the majority requests in the same moment (live moving pictures) is enhanced - seen from the individual consumer's view -by delivering additional specialised information wanted at an arbitrary time and by a limited number of people.

The exact opposite can be observed in the information distribution of today. These phenomena can best be described by examples:

Example 1: TeVeFonen: This Danish service delivers information targeted to one recipient over a network. Thus, every viewer can see the information required by the one recipient - though it is most likely to be of no interest at all. This means, that transmission capacity which could be used for information of general interest is allocated to the service of one single citizen (as opposed to sending directly to the recipient via e.g. the internet).

Example 2: Internet Radio: Here, a large group of people wish to view an event simultaneously and real-time (i.e. they all watch it at the same time, and AS it happens). Distribution of such information, which inherently is of interest only (or almost only) in real-time would easily be transmitted via the cheaper and less sophisticated cable network, ground based networks, satellites or similar transmission technologies. Using the internet for mass distribution leads to congestion.

This is the reason for TVBoost. In this experimental service, we attempt to deliver the specialised information over the internet - and leave it to the broadcast companies to deliver the information which all viewers want at the same time.

Frequently Asked Questions about TVBoost

| Questions | Answers |
|---|--|
| Why is the background color magenta ? | Because magenta becomes transparent when overlaid a tv tuner window. This way you can view the TV transmission at the same time as the information on this page. |
| Does magenta transparency work with all systems ? | It is tested on an ATI All-in-Wonder graphics card under WinNT as well as Win95. Other configurations I'm not sure of. I'm investigating whether magenta transparency is a de facto graphics standard. If you know anything about the topic, please email me |

Bugs on TVBoost:

| Problem | Solution |
|---|--|
| When opened in Netscape, there's still a frame around the picture | None |
| When I open a new stage profile, it can't be seen. | The small window with the stage profile is behind the picture. Use alt-tab or the windows key on your keyboard to bring the to the front of the page. To avoid this in the future, always close the small stage profile window before activating any other link. |

Requirements:

1. Windows 95/98/NT
2. Microsoft Internet Explorer or Netscape Navigator (MSIE works best)
3. A PC TV tuner

Conclusion

TVBoost was a very successful prototype, as it proved that – given the right platform – html and the Internet could be used with good effect for providing supplementary text- and graphics based information to TV programmes. Considering that it was launched in 1999, when convergence phenomena were fewer and further between than today, it was a novel, yet simple approach to the problem of adding interactive services to television.

An important limitation is, that it can only be used on a TVPC. Though advertised in a Danish Usenet cycling group, testing of the service was limited, and other platforms that Wintel PCs were not considered. It is likely, however, that the concept will work on other operating systems and stand-alone Internet set-top boxes for TV sets. Further testing and definition of standards securing interoperability would be necessary for this to be reality.

Using the open standard of html, and benefiting from the low entry barriers for service providers on the Internet, a service such as TVBoost can be provided by virtually anyone interested. Private enthusiasts can contribute to TV programmes. Organisers of events – especially sports – can add value to their content by delivering additional information. The main problem is the limited installed base of appliances that are able to receive and display the content – and hence the limited potential audience for the service.

If in the future, TVPCs become more common, such an installed base would exist. If, alternatively, many TV sets in the future get html capability – by integrated features or external set top boxes, a different installed base would be in place, and there would be a sufficient potential audience for such services to be truly valuable.

Suggestion for stereoscopic adapter for LCD type projector

– basic introduction and specifications

By Alexander G. Oest, Center for Tele-Information, Technical University of Denmark, August 2000.

This paper suggests a new and innovative way of projecting stereoscopic applications and movies on to a screen for larger audiences. Compared to the existing systems for large audience stereoscopic presentations, this system is simple and flexible.

It uses virtually any current types of projector – even the cheap and abundant old LCD-projectors.

The system consists of a polarising and lens arrangement mounted in front of the projector. No software development is necessary, as a usable driver already exists. Furthermore, the format of most stereoscopic computer movies suits the system perfectly.

Basic assumptions or preconditions:

Assumed source of video signal: Computer

Assumed content: Stereoscopic movie or 3D application.

Assumed stereoscopic method: There are basically two ways of directing image to the correct eye: shutter glasses and polarisation. The suggested lens arrangement can be mounted with LCD shutter panels instead of polarising filters. However, the polarisation method is suggested due to its simplicity and the low price of glasses.

Overview of current solutions⁵²⁸:

1): One CRT-projector with shutterglasses using page-flipping source format.

- Pros: good image quality
- Cons: complex and expensive –projector as well as glasses.

2): Two stacked LCD-type projectors with polarisation filters and demultiplexer (separating right and left eye's images from page flipping source).

⁵²⁸ For a short but good description of stereoscopic techniques, see <http://www.stereo3d.com/faq.htm>

- Pros: acceptable image quality, smaller equipment, projectors commonly available. Inexpensive glasses – can be given away for free.
- Cons: complicated setup of projectors and demultiplexer. Expensive demultiplexer. Special non-depolarising screen necessary.

3): One DLP projector with shutterglasses using page-flipping source format.

- Pros: Theoretically easy setup and excellent picture quality. Reasonable price.
- Cons: Scarcity of DLP projectors (assumed), synchronisation of picture and shutterglasses often destroyed by the projectors built-in frame buffer.

Suggested solution:

One LCD projector with lens arrangement, polarisation filters and polarisation glasses, using split-screen format.

- Pros: Suitable movie format and stereoscopic graphics driver is already available. Cheap projector – cheap glasses. Easy setup.
- Cons: Lens arrangement has to be constructed – and might be complex to set up. Special non-depolarising screen necessary.

Elaboration on the suggested solution:

For showing stereoscopic content (movies, 3d applications etc.) to larger audiences, the choice of hardware is usually between one CRT projector or two LDC or DLP projectors. Both solutions are disagreeable due to their price, size and complexity.

A good solution is using polarised glasses and only one projector. However, to do this, it is necessary to divide the displayed image into sections intended for the right resp. left eye – known as screen splitting. In addition, the content (movie, computer game etc.) must be in such a form, that they can be divided accordingly.

Most stereoscopic movies are already in split screen format – or in interlaced format, which can easily be converted to split screen. In addition, several computer games for PCs use a 3D API (OpenGL, Direct3D or Glide), which contains stereoscopic information available through the Z buffer. A driver provided by Metabyte is able to display these games and applications in split-screen format.

The conclusion on the above is, that displaying stereoscopic movies and applications on a computer and LCD projector is possible – all that's missing is an arrangement of filters and lenses polarising and spreading right and left eye images onto a non-depolarising screen.

The basic principle of such a filter/lens arrangement is shown below. Polarising filters make sure that each half of the image can be seen with the corresponding eye only (as the spectators are wearing glasses with one eye polarised vertically, the other horizontally). The lenses will stretch the two half-images from their original 8:3 format to 4:3 format.

The lenses and polarising filters should be mounted in a rig or frame, so adjustment is possible. Adjustment should be aimed at making the two stretched half-images cover the same area on the screen.

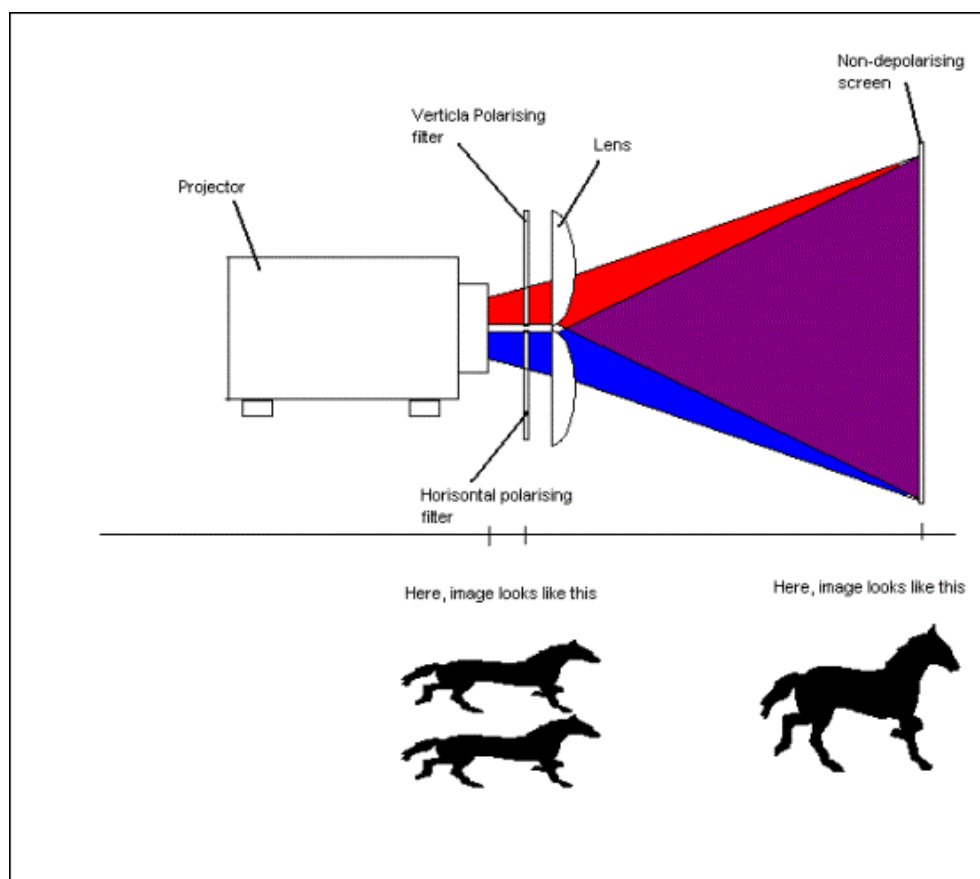


Figure 75: The principle of the stereoscopic projector adapter.

The task

The task remaining is selecting the appropriate lenses and constructing a frame in which they can be mounted. Hopefully, a couple of fairly standard lenses can be used. If so, the task is calculating the lenses' properties, not the actual manufacture of them.

Furthermore, polarising filters and non-depolarising screens corresponding with existing polarising glasses should be selected, but that should be fairly easy.

Finally, one needs to make sure, that the selected projector does not polarise the image before it leaves its lens. There is no clear knowledge on which projectors do and which do not. Further investigation and/or practical experiments are necessary.

Co-author Statement

Co-Author Statement describing the authors' contributions to the paper:

“New Standardisation Fora and Their Relationships with Traditional Standardisation Organisations”

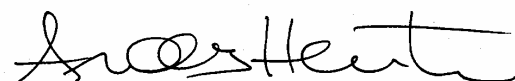
By

Alexander G. Oest and Anders Henten, Presented on the Communicate2000 Online conference.

Concerning the above paper, I hereby declare, that my contribution to the paper is limited to the following:

- The idea of comparing consortia to traditional standardisation organisations.
- The observation of shortened product life cycles in consortium standardisation.
- Contributions in formulating the text – in total less than five per cent of the complete paper.

Lyngby, Denmark, August 16, 2002



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